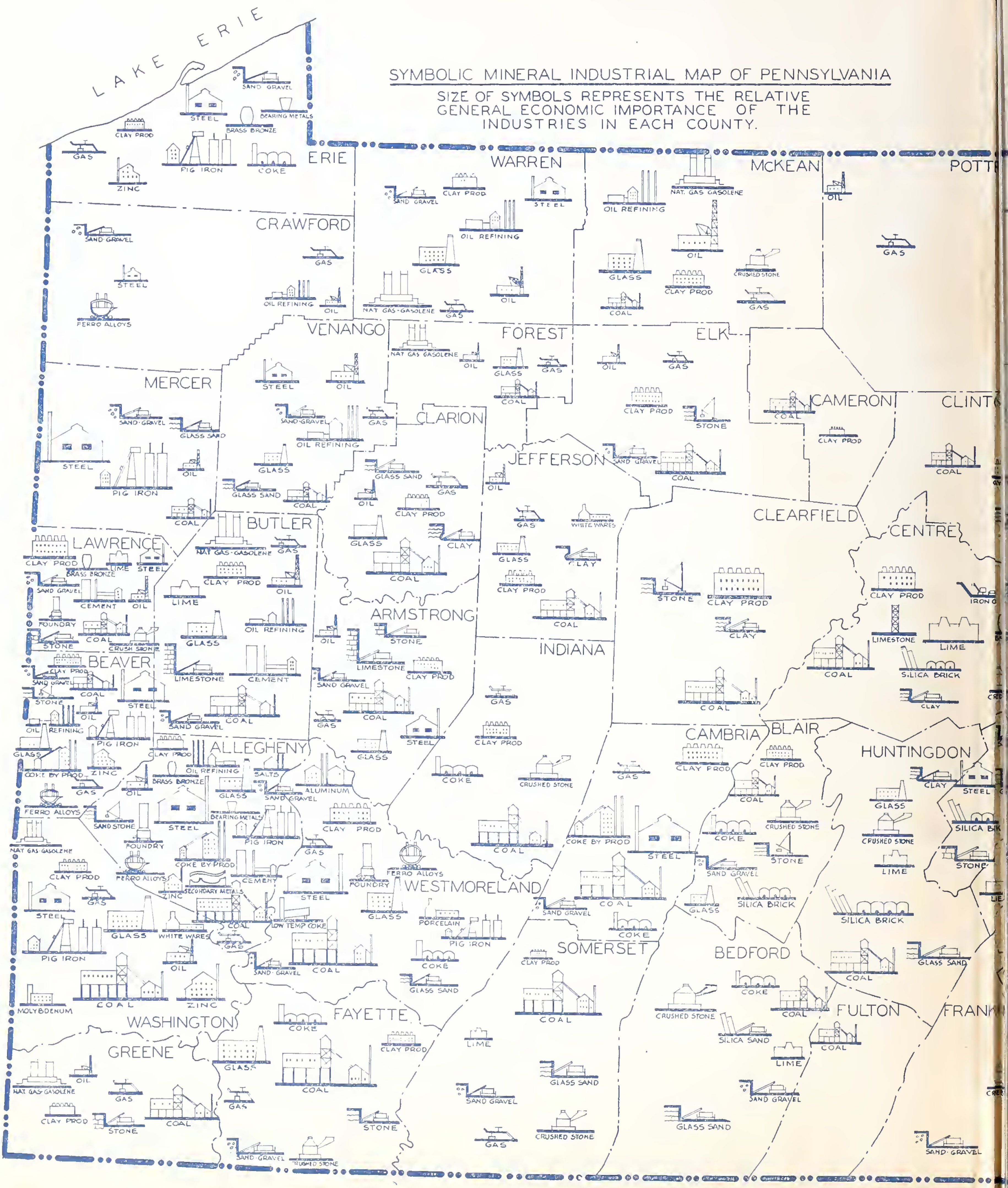
PENNSYLVANIA'S MINERAL HERITAGE

Published by the
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
WILLIAM S. LIVENGOOD, JR., *Secretary*

SYMBOLIC MINERAL INDUSTRIAL MAP OF PENNSYLVANIA

SIZE OF SYMBOLS REPRESENTS THE RELATIVE
GENERAL ECONOMIC IMPORTANCE OF THE
INDUSTRIES IN EACH COUNTY.



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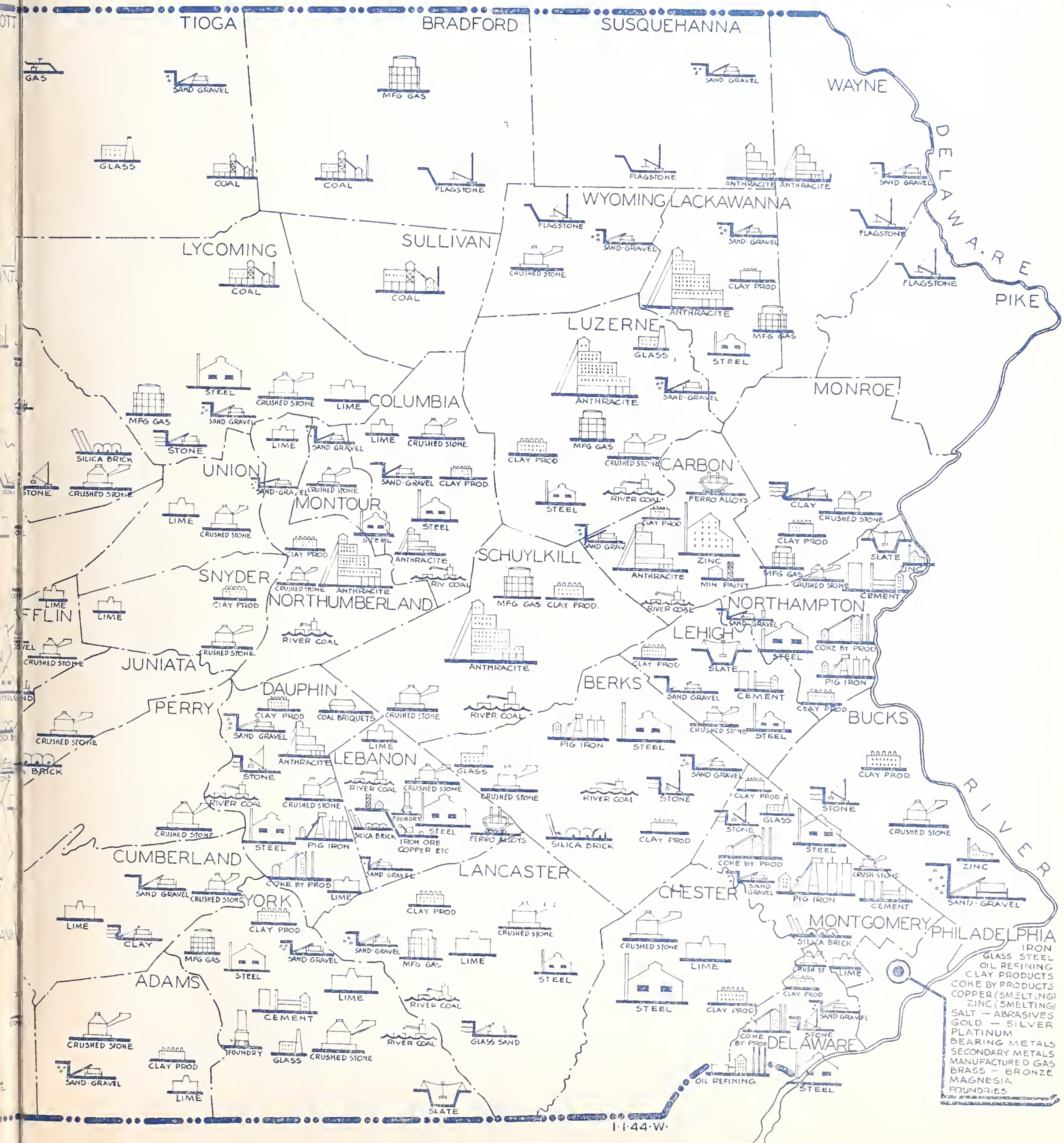

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PENNSYLVANIA'S MINERAL HERITAGE

The Commonwealth at the Economic Crossroads of Her Industrial Development

PENNSYLVANIA DEPARTMENT OF INTERNAL AFFAIRS
BUREAU OF STATISTICS
TOPOGRAPHIC AND GEOLOGIC SURVEY

THE PENNSYLVANIA STATE COLLEGE
SCHOOL OF MINERAL INDUSTRIES

Published by the
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS

WILLIAM S. LIVENGOOD, JR., *Secretary*

Harrisburg, 1944

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Department of Internal Affairs,
Harrisburg, Pennsylvania,
September 1, 1944.

To His Excellency, General EDWARD MARTIN,
Governor of the Commonwealth of Pennsylvania.

Sir:

As a contribution to your plan for the assurance of employment in Pennsylvania during the post-war period, and as a document for the use of those interested in the best use of our mineral deposits and the development of our manufactures, I submit herewith to you and the people of the Commonwealth a report entitled Pennsylvania's Mineral Heritage.

In accord with State law, the Department of Internal Affairs, over a long period of years, has gathered and has on file a vast accumulation of information relating to the mineral resources and the industrial development which has come into being largely because of the natural wealth with which God endowed our State.

Thousands of pages of scientific reports, hundreds of pamphlets and numerous bulletins have been published, setting forth the findings of the Bureau of Topographic and Geologic Survey and the Bureau of Statistics, but we know of no previous attempt to correlate the work of these two important branches of our State Government in a manner calculated to bring into closer and more useful relationship our remaining natural resources and our industrial machinery for the best and most economic utilization of the same. Recently our Department has received hundreds of requests for information of this character from individuals and corporations preparing to make the largest use of their properties when the time shall come to return to the ways of peace.

There exists also within the State governmental structure an agency whose functions are those of education and research in the mineral industries, namely, the School of Mineral Industries of The Pennsylvania State College, with which the Department of Internal Affairs has long had a cooperative agreement. These three agencies are admirably equipped to pool their information and by cooperative action to present a comprehensive picture of all phases of the significance of the mineral industries in the economic development of Pennsylvania.

For the past hundred years or more Pennsylvania's minerals have dominated its economy. In strictest sense the "common wealth" has been, and is now, mineral wealth. In other words the Keystone State might just as well be called the "Mineral-wealth" as it is the Commonwealth of Pennsylvania.

Settlement of Pennsylvania, and its subsequent development, were largely promoted by two dominant motives—the ambitions of adventurous newcomers to improve their fortunes and the hope of oppressed people to escape from thraldom of tyrannical government into an atmosphere of enlarged personal liberty and freedom of worship.

To assure and perpetuate these principles was the purpose back of the "Commonwealth" plan of government laid down by William Penn when he became proprietor of the colony.

Three factors above all others entered into Pennsylvania's development, namely:

First, the thrift, enterprise, vision and energy of an intensely active and ambitious people, exhibiting the best qualities of many merging nationalities, intent upon improving their own conditions, and those of their children.

Secondly, the constitutional foundation of government inherited from Penn and further liberalized by succeeding generations, affording freedom of conscience, freedom of opportunity and freedom of action.

Finally and necessary to the efforts of these enterprising people there were and are the natural resources of great abundance and wide diversity of character and location for which Pennsylvania is famous.

That Pennsylvania people in their haste to develop and achieve have been wasteful and that the cream has been skimmed from our natural mineral resources is admitted. On the other hand, we have now the industrial machinery and the technical leadership, which, if properly applied, should enable us to use the vast resources still at our command in a manner to insure work and prosperity for the people of Pennsylvania for untold generations to come.

The purpose of this report, then, is to provide at once a source of accurate information for those interested in further industrial development of our mineral industries, in the immediate post-war period, and a text book for library, college and school use. This report is designed to aid in the furtherance of many industrial and transportation surveys now being made and as a help in future studies. It is intended to be useful in the encouragement of post-war employment and as an educational instrument for the long haul—with revision from time to time to keep it up to date. To these ends the work herewith begun should be continued through the three agencies named—the Bureau of Topographic and Geologic Survey and the Bureau of Statistics of this Department, and the School of Mineral Industries of The Pennsylvania State College.

The Geologic Survey must continue its work of providing detailed inventories of mineral resources known or yet to be discovered. The Bureau of Statistics should be expanded and the School of Mineral Industries must continue to lead the way in education, including research.

Pennsylvania's elaborate and highly efficient systems of transportation, including steam railroads, electric, bus and truck systems, power lines, pipe lines and communications—should very properly have a part in this report, but since maps and descriptions of some of these might be of use to the enemy, information relating thereto must await the coming of peace.

It is desirable to add a chapter on this subject at a later date for the reason also that most of these agencies are now preparing to undertake many enlargements, improvements, changes and revisions immediately upon the conclusion of peace to an extent that would make any present attempt at description obsolete and useless within one year after the war has ended.

Since nearly half of the revenue of Pennsylvania is derived from primary mineral industries, the Commonwealth can well justify the expenditure of public funds on the utilization and conservation of our remaining resources through the three functions of the School of Mineral Industries, as necessary to any rehabilitation program for Pennsylvania —namely, resident instruction to train future leaders, extension instruction to train workers in new processes, and through research to solve economic and technical problems. Machinery for this is already established, and the School is the only one of its kind in Pennsylvania uniting all three functions. During the period of cooperation leading up to the completion of this report I have been convinced that the present program of the School is in good faith with the Organic Land Grant Act. Five special appropriation bills for mineral industries research in recent sessions of the Legislature testify to popular interest, and close industry-education cooperation is indicated by industrial grants-in-aid to the School totaling several hundred thousand dollars.

I am strongly of the belief that further cooperation of the agencies of the Department of Internal Affairs and the School—on an even broader scale—is not only desirable, but imperative as essential to the proper use of our remaining mineral resources, the future economical development of our mineral industries and the gainful employment and continued prosperity of the people of Pennsylvania.

WILLIAM S. LIVENGOOD, JR.

ACKNOWLEDGMENTS

This publication represents a cooperative effort on the part of the Department of Internal Affairs and the School of Mineral Industries of The Pennsylvania State College. William S. Livengood, Jr., Secretary of Internal Affairs, appointed the following committee to supervise the preparation of this volume: From the Department—Dr. George H. Ashley, State Geologist, Bureau of Topographic and Geologic Survey; Henry W. Van Pelt, Director, Bureau of Statistics; G. M. Steinmetz, Director, Bureau of Publicity and Information. From the School of Mineral Industries—Dr. Edward Steidle, Dean; Dr. W. M. Myers, Associate Professor of Mineral Economics; and Dr. A. W. Gauger, Director, Mineral Industries Experiment Station.

Part I, Statistics of the Mineral Industries, has been prepared under the direction of Henry W. Van Pelt, with the assistance of Elmer T. Larson and others of the Bureau of Statistics staff. Part II, Mineral Resources, has been prepared under the supervision of Dr. George H. Ashley, with the assistance of Dr. Ralph W. Stone and other members of the Geologic Survey staff. Part III, Technology and Mineral Resources, has been prepared under the supervision of Dr. W. M. Myers, with the assistance of staff members of the School of Mineral Industries.

As many different persons have contributed to this study, wherever opinions are expressed, they are those of the individual contributors.

Illustrations are mostly reproductions of paintings in the School of Mineral Industries Art Gallery at State College.

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GEOGRAPHIC FACTORS IN THE DEVELOPMENT OF THE MINERAL INDUSTRIES OF PENNSYLVANIA

IN three centuries Pennsylvania has evolved from a wilderness into the greatest mining and mineral industries State in the Union. Geographic factors have guided this development, and, in a broader sense, have been responsible for Pennsylvania, rather than some other State, having attained premier place. Pennsylvania is now paying the price for pioneering and is rapidly losing many of her initial advantages. Every citizen must appreciate this fact: Pennsylvania must now fight to hold what she has won.

The Time Factor

Pennsylvania, the workshop of the Nation, was slow to take up her heritage as the greatest mineral State in the Union. William Penn, it is said, requested his colonists to keep a sharp lookout for minerals that might prove useful, but apparently neither he nor anyone else visualized the immense possibilities inherent in our mineral wealth.

Knowledge that mineral resources were present was not slow in accumulating. In fact, the Indians were aware of their existence long before white men arrived. They knew that the hills in many places were underlain with black stones that would burn, that there were oil seepages and salt springs. They were familiar, also, with outcroppings of iron and of lead and zinc even though they could make little use of them other than for pigments. But mere awareness was not enough.

Other things than knowledge of the existence of the minerals were necessary before the State's treasure chest could be unlocked. Early in Pennsylvania history the time factor was not right. Better means of transportation were necessary and better markets. A population of 100,000 (in 1740) confined almost entirely to the southeastern corner of the State had very little need for the vast mineral wealth farther inland. They had wood to heat their homes and water power to turn the wheels of their small industries—all near at hand. They had no use for coal without the means to transport or the machinery to burn it.

They did have need for several of the metals: iron for pots, nails, and various and sundry other articles; lead for bullets; copper for sheathing and the manufacture of pewter. Iron was found fairly early not far up the Schuylkill River from Philadelphia. Twenty-five years after the founding of the Colony, castings and forged pieces were sent by way of the Schuylkill to Philadelphia where they were sold.

The Role of Streams

After the population and consequently the market had increased to the point that there was sufficient demand for the wealth that lay in Pennsylvania's hills, the means to transport it slowly evolved. It was the stream systems of Pennsylvania that furnished the guiding pattern in mineral production throughout the years from the founding until the present. Streams led the way into the hills, often uncovering the resource itself. Streams often carried the product of the mines to market, down the Schuylkill to Philadelphia, down the rivers to Pittsburgh. In some places the streams themselves sufficed; elsewhere, canals were built paralleling the streams, using their valleys and their water. Even during the railroad period the stream pattern prevailed, for railroads made use of the easy grades of stream valleys wherever they possibly could. And now the highway and trucking period still makes excellent use of the stream valleys, although highways have considerably more flexibility than any of the previous transportation methods.

It is hard to think of any other important mining region in the world so dominated by stream patterns as is Pennsylvania. The relative hilliness of the State put a premium on the easy grades afforded by valleys. As early as 1840 the picture of the Anthracite Region was one of a wooded, mountainous area practically untouched except at three widely separated points where it was tapped by streams that led to markets in Philadelphia or New York (Figure 1). The streams themselves were too turbulent to be directly useful for navigation. Consequently, canals were built: one paralleling the Lehigh River, one following the Schuylkill, and a third making use of Lackawaxen Creek and the upper Delaware River. In each case the areas tapped were marginal to the Anthracite Region: Mauch Chunk on the upper Lehigh, Pottsville at the edge of the Anthracite Region on the Schuylkill, and Carbondale at the extreme northeastern end.

At a later date (1870) three streams, the Lehigh, Schuylkill, and the Susquehanna, still played impor-

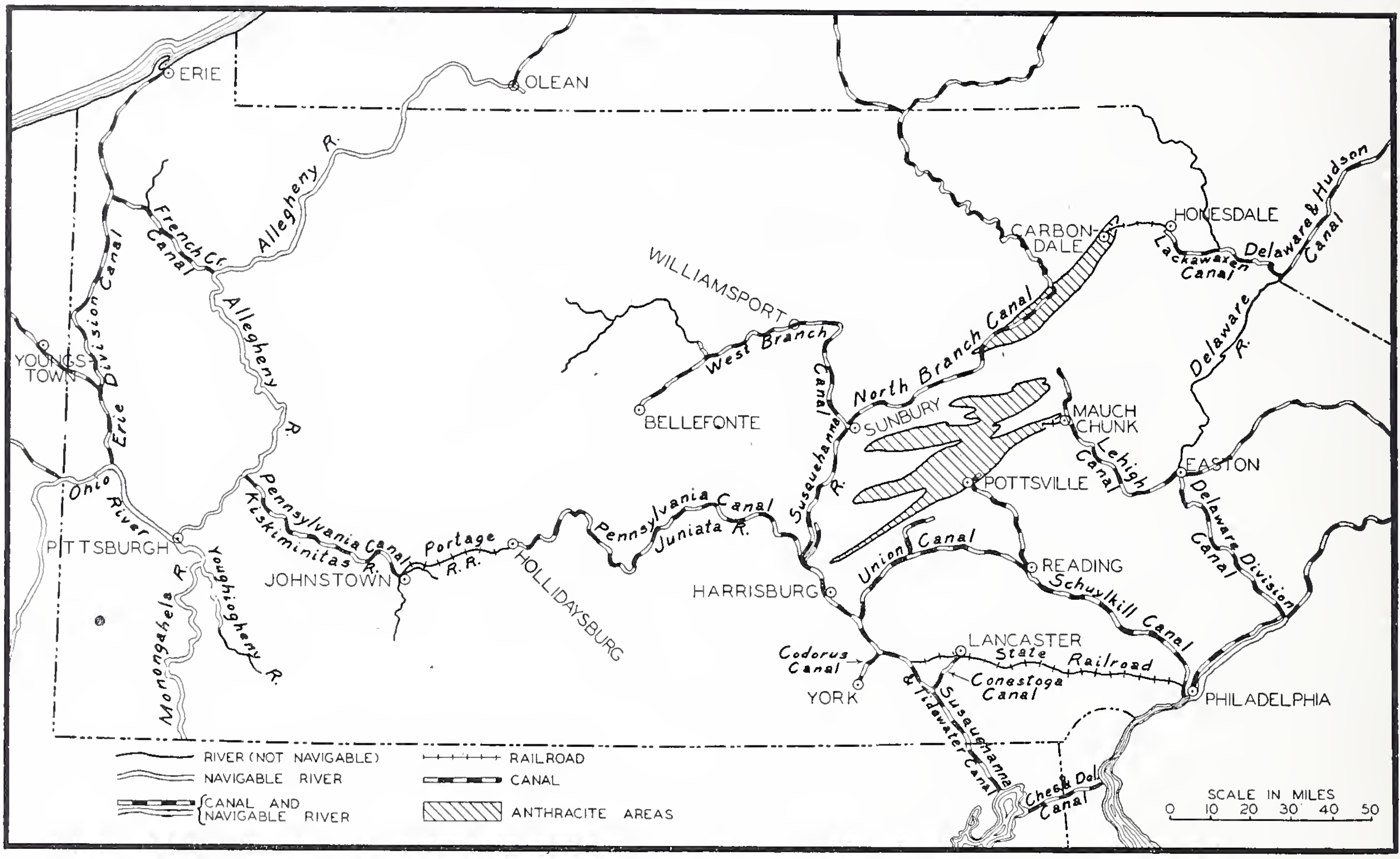


FIGURE 1. RELATIONSHIP OF STREAMS AND CANALS TO ANTHRACITE REGION

tant roles in carrying anthracite from the mines downstream to the numerous blast furnaces located along the streams. During this period ten or a dozen furnaces were to be found along each waterway, the upper reaches of the stream tapping the coal region and the lower reaches furnishing the sites for the iron industry.

The streams of western Pennsylvania also played their part in developing the mining and mineral processing picture of the State. Early bituminous coal mining centers appeared along the courses of the Monongahela and Allegheny Rivers where transportation was furnished by the streams themselves. Pittsburgh at the forks of the Ohio became known as "the smoky city" as early as 1807 because coal mined along the rivers was so plentiful and cheap that it was widely used as a domestic fuel. Pittsburgh's stream junction location was directly responsible for its early function as a metal finishing point, which led to its eventual position in the primary iron and steel industry. Pittsburgh in the early days, after the opening of the Ohio Valley for settlement, became an outfitting point for pioneers moving westward down the Ohio to new lands. Since the trip from Philadelphia was overland and difficult, the pioneers arrived at the forks of the Ohio without many of the things necessary to start a home in the new territory. Pittsburgh consequently began to manufacture secondary metal products as well as boats to outfit pioneers for the West. Primary iron was not made at Pittsburgh, but the metal could be brought in by way of the rivers, some of it coming overland from central Pennsylvania to Johnstown and the Allegheny drainage.

Even at a later day, when Pittsburgh had a primary iron and steel industry of its own, the rivers played their part in its development. Iron ore moved in by way of the Great Lakes and by rail, routed through the Beaver and Allegheny valleys. Coke made in the Connellsville district moved by barge down the Youghiogheny to meet the ore at Pittsburgh. The finished primary iron and steel often moved to markets down the Ohio or eastward by way of the Pennsylvania Railroad, which follows the Conemaugh Valley west of the crest of the Alleghenies and the Juniata to the east.

The Juniata Valley has given location to two other mineral industries, the quarrying of glass sand and the manufacture of silica brick. Glass sand and ganister are widely distributed but are quarried only where the river valley has given greatest accessibility.

Another mineral industry developed along the Kiskiminitas River but has since disappeared. Salt wells were drilled near the river; coal mined nearby was used to evaporate the brine. The salt produced was shipped east by canal along the Conemaugh and Juniata waterways and west by way of the Ohio and Mississippi Rivers. In this fashion a stream again served to localize an industry and at the same time served as a transportation route to carry the manufactured product to market.

The Allegheny River played an important role in still another mineral development, for it was in its valley that the petroleum industry of western Pennsylvania first came into being. Early drilling followed the shores of the river and its tributaries, partly to use the water for easy transportation and partly because oil men of that time were convinced that the oil underground somehow followed a course similar to that of the surface streams. Many years elapsed before the oil industry tore itself away from the stream pattern. Even today most of the refining centers are located along streams.

So the picture grew, the mineral industries repeatedly following the streams by canal, railroad, and highway. At first only the major streams were important. Then as mining progressed and there was greater need, the smaller tributary streams began to show up in the pattern. Finally, the picture has become one in which the stream patterns of the State are reflected in the mining and industrial pattern, in the distribution of population, and in many other items of the present day.

Broader Elements of Pattern

At the same time development has gradually come to reflect the extent of the mineral resources in their broader outlines. Thus, though most of the bituminous coal mines are in stream valleys, yet in a larger sense they are distributed over the whole vast soft coal region of western and southwestern Pennsylvania; and the distribution of oil and gas wells over the State has come, in time, to reflect the northeast-southwest belt of oil and gas occurrence in the State. The haphazardness of pioneer development is gone. The Commonwealth has reached maturity in the development of her resources.

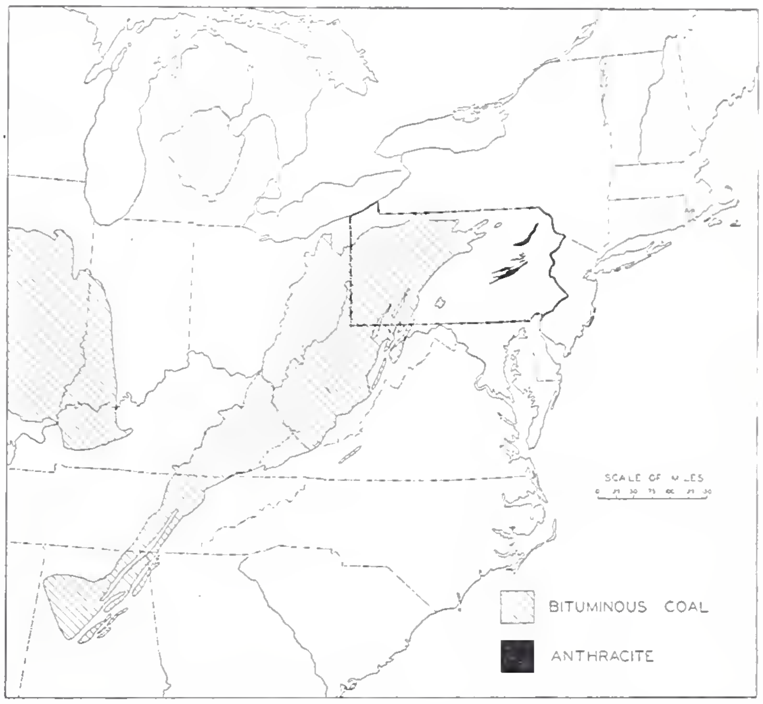


FIGURE 2. COAL FIELDS IN EASTERN UNITED STATES

The Location Factor

Next to the actual possession of the resources, Pennsylvania owes her rise as a mineral industries State chiefly to an excellent location. Straddling the Appalachians with their great coal resource, with one foot on the Atlantic Coast and the other in the Ohio Valley, the Commonwealth was foreordained to play a stellar role in the country's industrial growth. In addition, Pennsylvania happened to lie at the northern end of the Appalachian soft coal belt (Figure 2)—near New England, with her early industrial start; near New York City, with its natural lowland route to the interior; and in the general section of the country that was nearest to Europe. Pennsylvania, like New York State, chanced to be in the pathway of traffic between Europe, with which the United States normally has most trade, and the Central States, our greatest agricultural section and greatest source of iron ore. All this gave Pennsylvania a great initial advantage over the States farther south in the Appalachian Highland that also contained coal and oil resources. Pennsylvania was in a position to take part in the early industrial development of the Atlantic Coast and then to follow industry's westward expansion across the Appalachians.

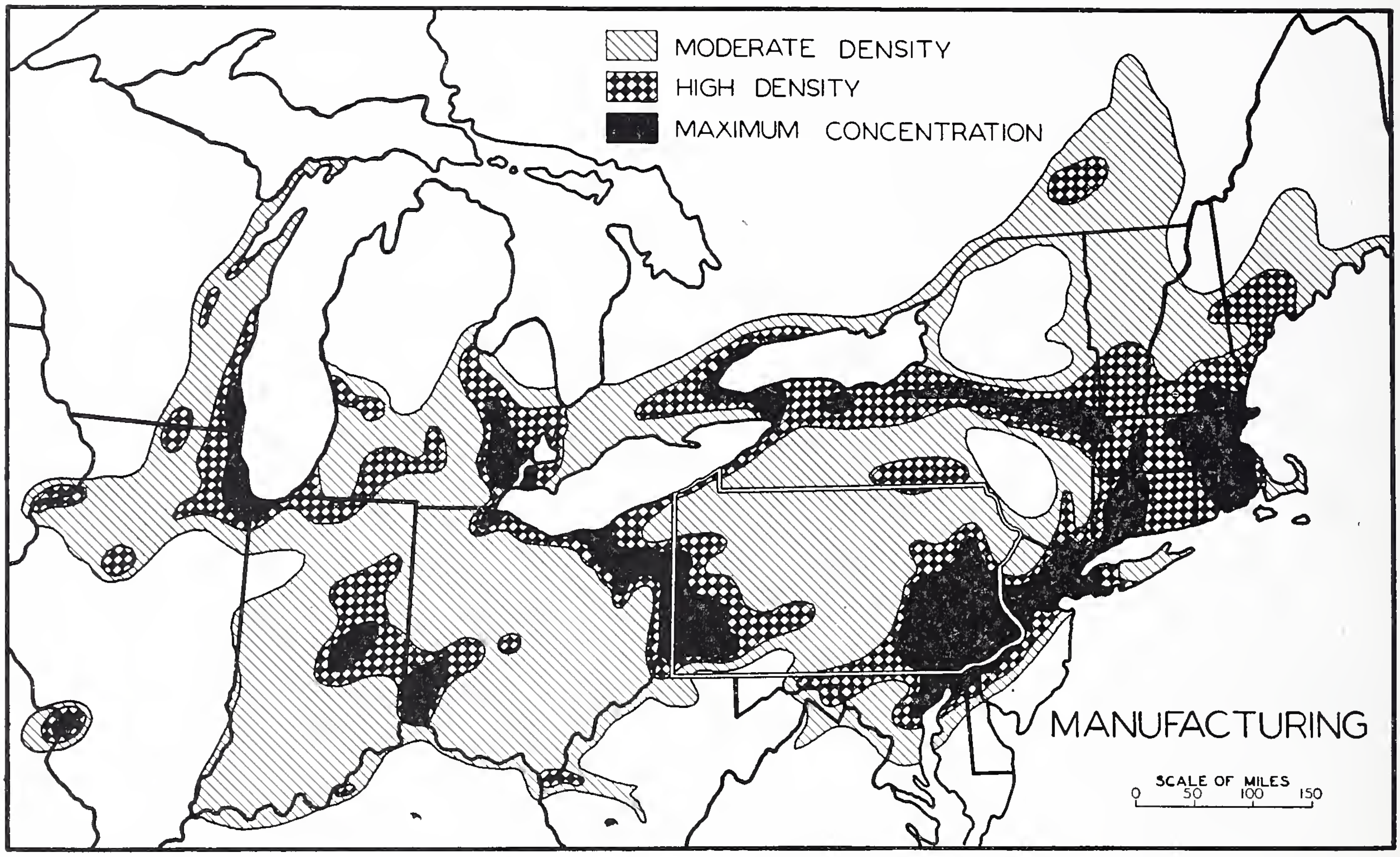


FIGURE 3. DENSITY OF MANUFACTURING IN PENNSYLVANIA AND ADJACENT AREAS

Of course it is a moot question to what extent Pennsylvania merely profited from a favorable location in industrial northeastern United States and to what extent Pennsylvania resources helped to bring into being the industrial region of which the State is now so important a link (Figure 3). But there is no doubt about the result. A courageous, venturesome, thrifty, skillful, pioneering people took advantage of a combination of favorable circumstances and produced a highly developed industrial region based upon one of the greatest mining areas of the world. Closely packed cities and populous rural districts brought about by mining and manufacturing created a demand for more coal and oil, as well as for vast quantities of common rock products such as stone, brick, cement, lime, glass, and clay. Thus Pennsylvania profited by her good location in the industrial northeast while at the same time industrial northeastern United States profited by the presence of Pennsylvania.

The Changing Picture

Unfortunately, neither resources nor other initial advantages last forever. The very fact that Pennsylvania got off to such an early start in her mineral industries brought its own penalties. Our coal resources, though still very great, are more nearly depleted and in many cases more expensive to mine than are those of States farther south. Our oil industry is long past its flush stages. Even the advantage of our location is declining. The country's center of population is moving westward and the growth of population and of industrial development in the Central and Southern States is a dangerous sign. These areas have lower costs, and large resources that are just beginning to be developed. If Pennsylvania is to hold her place as the leading mineral-industries State, extensive research coupled with increased application of technical skill will have to make up for declining natural advantages.

THE MINERAL INDUSTRIES IN PENNSYLVANIA

THE original endowment of Pennsylvania was conspicuous for the variety of minerals present and the tremendous tonnages in which the most useful and desirable types occurred. The utilization of this material has been the most important factor in the economic and industrial development of the Commonwealth. About 350 different mineral species have been found and identified in Pennsylvania. About 10 percent of this number have proved to be of great commercial importance. The mineral reserves that accumulated during the millions of years of geologic history have been drawn upon for some 250 years. Consumption at first was of a trifling nature and it is only since 1900 that the depletion of mineral resources has become a serious matter. In this short interval great inroads have been made in this irreplaceable asset.

Pennsylvania established leadership as a producer of minerals at an early date. From the earliest date up to 1935 Pennsylvania led the United States in the production of mineral wealth. In 1935 Texas, favored with a great flood of petroleum, took over first place and has retained it to date. As a producer and processor of mineral products Pennsylvania has no rival and it is this fortunate combination of mineral raw materials, fuels, and technical skills upon which the industrial life of the Commonwealth is dependent.

Before 1900, the workers in the mineral industries of Pennsylvania produced about one-half of the total mineral wealth of the United States. Since 1900 there has been a constant decrease in the percentage of the Nation's total mineral wealth that is produced by our State. This decline is relative and is due not to a drop in actual production but to the increase in production in some of the States to the west and southwest. The annual value of mineral production in the Commonwealth naturally has displayed considerable fluctuation. The general industrial stagnation of the 1930's was accompanied by a substantial decrease in output. The widespread stimulation of all activity by the war has caused capacity operation of our mineral industries. It is significant that the annual dollar valuation of mineral production in Pennsylvania has exceeded one billion dollars in four separate years, a record not yet attained by any other State.

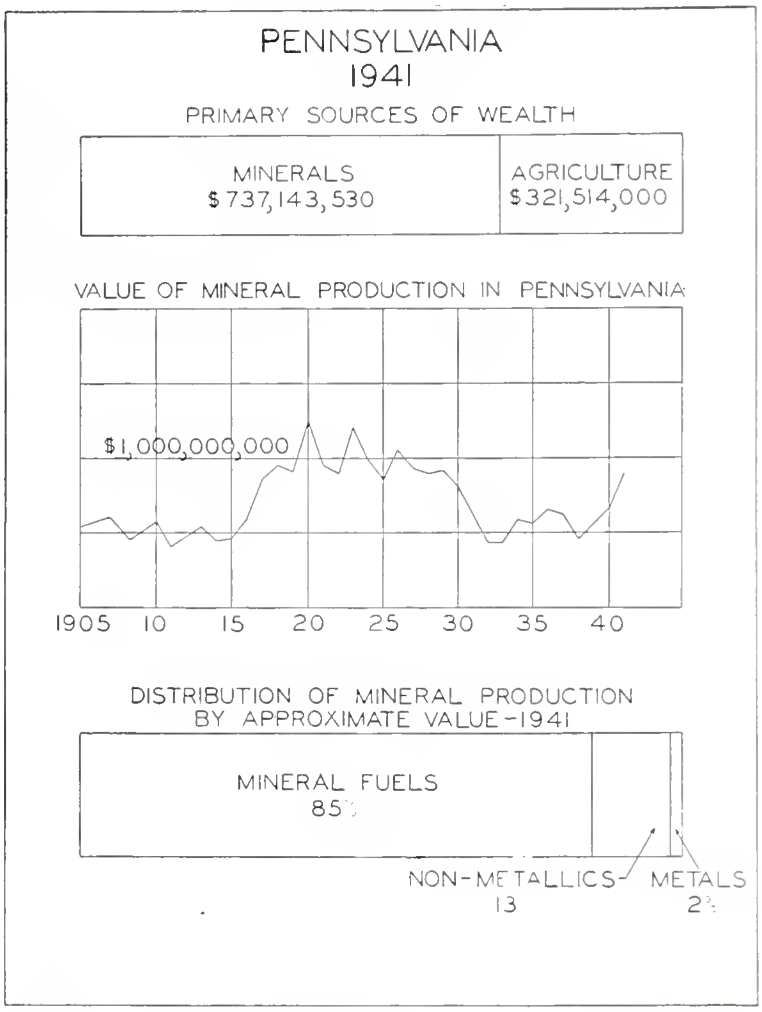


FIGURE 4. MINERAL PRODUCTION IN PENNSYLVANIA

As a matter of convenience the mineral production of the Commonwealth may be divided into three classes: the mineral fuels, the nonmetallics, and the metals. On the basis of valuation the mineral fuels are by far the most important group. They normally contribute about 85 percent of the total. The nonmetallics rank next with an average contribution of 13 percent. The metallic ores supply the remaining 2 percent. This is shown in Figure 4.

Measured by quantity Pennsylvania is the leading producer of anthracite, raw clay, mineral paints, stone, cement, coke and associated byproducts, pig iron, ferro-alloys, steel, glass, and refractories. It is second as a producer of lime and bituminous coal. It also leads the country in the production of metallic zinc and sulphuric acid obtained from sulphide ores originating outside the State.

PART I

STATISTICS OF THE MINERAL INDUSTRIES

Compiled by the

BUREAU OF STATISTICS

HENRY W. VAN PELT, *Director*

THE mass of available statistics relating to the mineral industries consists of a collection of facts and figures from many sources. All the more important statistical series covering minerals in Pennsylvania have now for the first time been assembled in one place and are presented on the following pages. Like all other records of human endeavor they are necessarily incomplete and contain some error. In general, they are conservative and on the low side because they report the production of record only. Unrecorded production would swell the total to an unknown degree. It is reasonable to assume, however, that the figures of record represent a very large percentage of total production, inasmuch as it has been the smaller producers who have been omitted.

Statistics in Industry

The rapid industrialization of the United States, which has been so dependent upon the development of mineral resources, has resulted in the demand for accurate data relative to all aspects of business activity. This has been one of the major influences in the development of the science of statistical methods, which has been able to apply advanced mathematical principles to the solution of complex problems. Such statistical procedures are possible only when the fundamental facts, such as appear in the following pages, have been collected and made available for analysis.

Federal Sources

Conspicuous among the more important sources of information which have been consulted in the preparation of the present publication are the following. First we must name the Census of the United States, inaugurated in 1790 and continued at ten-year intervals to date. This branch of the Federal service, which unfortunately brings to the minds of many persons only an enumeration of the population, has developed into an organization of amazingly comprehensive scope, the more recent publications of which supply a wealth of detail relative to the vast range of the nation's industries. In addition to appearing in the complete volumes of the United States Bureau of the Census, part of this information is conveniently summarized in the "Annual Statistical Abstract of the United States," prepared by the Bureau of Foreign and Domestic Commerce in the United States Department of Commerce.

Minerals Yearbook

Information concerning the mineral resources of the United States and their utilization was systematically assembled for the first time by the United States Geological Survey, a Bureau in the Department of the Interior. The first volume entitled "Mineral Resources of the United States" was issued for the year 1880. Publication on an annual basis was continued until 1924, when the responsibility for preparation was transferred to the United States Bureau of Mines, now also a Bureau in the Department of the Interior. In 1932 the name of the publication was changed to "Minerals Yearbook," under which title the annual volume has since appeared. This incomparable series supplies the most valuable single source of information in existence relative to the origin and growth of the mineral industries in this country and in the several States. Fortunately the early editors appreciated the importance of an historical record and preserved extensive production data which otherwise would have been lost.

Trade Statistics

The annual volumes published by the American Iron and Steel Institute and the American Petroleum Institute are models of statistical information and have been consulted freely. Though unofficial in the sense that they are not compiled by a governmental agency, they are generally recognized as excellent examples of trade association statistics which have been carefully gathered and have attained a reputation for reliability equal to many of the best governmental sources.

State Sources

The Commonwealth of Pennsylvania has recognized that it can not conduct the affairs of State intelligently or efficiently without exact data relative to the various economic factors involved. This led to the early establishment of the Bureau of Statistics in the Department of Internal Affairs. Among the many services per-formed by this Bureau is the taking of an annual inventory of Pennsylvania's manufacturing and mining industries. The information compiled as a result of these comprehensive annual surveys supplies, particularly for individual counties and cities, information available from no other source.

It is hoped that the present study in mineral economics, the first part of which deals with mineral statistics, will serve as a record of accomplishment and as an inspiration to further progress.

TABLE 1. VALUE OF MINERAL PRODUCTS OF THE UNITED STATES AND PENNSYLVANIA

Year	*United States*	*Pennsylvania*	*Percentage of total*
1880	$367,463,000	....	...
1881	403,120,000	....	...
1882	453,106,000	....	...
1883	448,061,000	....	...
1884	407,040,000	....	...
1885	419,551,000	....	...
1886	456,185,000	....	...
1887	535,633,000	....	...
1888	553,799,000	....	...
1889	542,326,000	....	...
1890	615,429,000	....	...
1891	600,849,000	....	...
1892	622,232,000	....	...
1893	545,493,000	....	...
1894	550,245,000	....	...
1895	642,691,000	....	...
1896	641,041,000	....	...
1897	651,612,000	....	...
1898	727,042,000	....	...
1899	1,010,096,000	....	...
1900	1,108,936,000	....	...
1901	1,155,078,000	....	...
1902	1,327,951,000	....	...
1903	1,495,381,000	....	...
1904	1,359,181,000	....	...
1905	1,623,765,000	$569,828,673	35.1
1906	1,900,880,000	657,413,780	34.6
1907	2,069,570,000	657,783,345	31.8
1908	1,591,773,000	473,083,212	29.7
1909	1,887,107,000	549,860,811	29.1
1910	1,987,844,000	591,602,573	29.8
1911	1,924,081,000	414,426,962	21.5
1912	2,237,794,000	445,790,022	19.9
1913	2,433,545,000	506,341,809	20.8
1914	2,111,172,000	445,264,824	21.1
1915	2,394,644,000	448,935,291	18.7
1916	3,508,439,000	554,501,375	15.8
1917	4,992,496,000	869,800,965	17.4
1918	5,540,708,000	979,245,098	17.7
1919	4,623,770,000	918,048,917	19.9
1920	6,981,340,000	1,314,332,585	18.8
1921	4,138,500,000	944,688,650	22.8
1922	4,647,290,000	823,148,222	17.7
1923	5,986,500,000	1,225,036,404	20.5
1924	5,305,800,000	1,011,630,879	19.1
1925	5,677,630,000	867,196,142	15.3
1926	6,213,600,000	1,055,766,077	17.0
1927	5,530,000,000	936,773,189	16.9
1928	5,385,200,000	881,490,033	16.4
1929	5,887,600,000	892,913,833	15.2
1930	4,764,800,000	778,523,421	16.3
1931	3,166,600,000	594,642,786	18.8
1932	2,461,700,000	424,734,073	17.3
1933	2,555,100,000	421,846,539	16.5
1934	3,325,400,000	546,932,552	16.4
1935	3,650,000,000	520,575,611	14.3
1936	4,556,800,000	599,457,486	13.2
1937	5,413,400,000	599,817,364	11.1
1938	4,363,200,000	472,773,327	10.8
1939	4,914,200,000	531,007,890	10.8
1940	5,613,900,000	618,347,805	11.0
1941	6,878,000,000	737,143,530	10.7
1942	7,569,500,000	839,000,000	11.1

NOTE: Separate figures for Pennsylvania first available for 1905.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook,* published by U. S. Geological Survey and U. S. Bureau of Mines.

ANTHRACITE

The anthracite industry is peculiar to Pennsylvania, that is, although a small tonnage of similar coal is produced in other States, it is in Pennsylvania alone that the mining and distribution of this coal has become a great industry. Production displayed an almost continuous increase from its origin up to 1917, tending to correspond with improvements in transportation and growth in population. Production culminated in 1917 with a tonnage just under 100,000,000 tons. There have been single years when the value of production exceeded half a billion dollars. In its years of prosperity anthracite mining was one of the country's greatest industries.

The decline of anthracite production from 1917 to 1938 has also been almost continuous. This drop in production has been the most serious recorded by any of the leading mineral industries of Pennsylvania. As recorded production for 1938 was slightly above 46 million tons the decline in volume was of a magnitude seldom paralleled in American industry. The associated decline in employment, real estate values, railroad revenues, and in volume of dependent industries has created the greatest single economic and social problem that has appeared to date in the Commonwealth.

The rise of competitive fuels for home heating, a field previously dominated by anthracite, is the principal cause for this decline. Coke, bituminous coal, natural gas, and petroleum have all appeared as competitors. Millions of tons of anthracite annually have been replaced by petroleum which, up to the outbreak of the war, was available abundantly at a low price. Since 1938 anthracite production has surged upward and a portion of the lost market has been regained.

An unknown but substantial tonnage of anthracite has been mined and sold through bootleg channels. This activity has been conspicuous since 1930. Accurate figures for production are not available. It has been estimated that production in single years has amounted to 10 million tons. Attempts to estimate the true anthracite producion for these years should make allowance for this production.

TABLE 2. ANTHRACITE PRODUCTION IN PENNSYLVANIA

Year	*Net tons*
1769	20
1770	50
1771	100
1772	100
1773	100
1774	100
1775	100
1776	200
1777	200
1778	100
1779	100
1780	100
1781	100
1782	100
1783	100
1784	150
1785	150
1786	200
1787	200
1788	200
1789	200
1790	200
1791	200
1792	250
1793	250
1794	250
1795	250
1796	250
1797	250
1798	250
1799	250
1800	250
1801	250
1802	250
1803	300
1804	350
1805	400
1806	400
1807	450
1808	950
1809	1,450
1810	2,200
1811	2,200
1812	2,300
1813	2,300
1814	2,400
1815	2,400
1816	2,400
1817	2,400
1818	2,700
1819	3,200
1820	4,065
1821	3,666
1822	5,533
1823	10,106
1824	15,278
1825	43,119
1826	61,393
1827	79,707
1828	102,944
1829	149,187
1830	234,790
1831	257,958
1832	501,951
1833	663,275
1834	511,682
1835	759,939
1836	924,816
1837	1,163,950
1838	977,775
1839	1,072,328
1840	1,129,206
1841	1,262,246
1842	1,440,986
1843	1,656,397
1844	2,127,653
1845	2,625,757
1846	3,032,199
1847	3,726,414
1848	4,001,418
1849	4,171,789
1850	4,326,969
1851	5,813,573
1852	6,412,166
1853	6,652,635
1854	7,668,143
1855	8,606,687
1856	8,959,739
1857	8,618,223
1858	8,807,938
1859	10,092,013
1860	10,983,972
1861	10,245,156
1862	10,186,435
1863	12,267,446
1864	13,027,168
1865	12,076,996
1866	15,783,977
1867	16,067,121
1868	17,707,722
1869	18,340,759
1870	19,958,064
1871	19,464,978
1872	24,734,173
1873	25,626,631
1874	24,267,472
1875	23,120,730
1876	22,793,245
1877	25,660,316
1878	21,689,682
1879	30,207,793
1880	28,649,812
1881	31,920,018
1882	35,121,256
1883	38,456,845
1884	37,156,847
1885	38,335,974
1886	39,035,446
1887	42,088,197
1888	46,619,564
1889	45,546,970
1890	46,468,641
1891	50,665,431
1892	52,472,504
1893	53,967,543
1894	51,921,121
1895	57,999,337
1896	54,346,081
1897	52,611,680
1898	53,382,644
1899	60,418,005
1900	57,367,915
1901	67,471,667
1902	41,373,595
1903	74,607,068
1904	73,156,709
1905	77,659,850
1906	71,282,411
1907	85,604,312
1908	83,268,754
1909	81,070,359
1910	84,485,236
1911	90,464,067
1912	84,361,598
1913	91,524,922
1914	90,821,507
1915	88,995,061
1916	87,578,493
1917	99,611,811
1918	98,826,084
1919	88,092,201
1920	89,598,249
1921	90,473,451
1922	54,683,022
1923	93,339,009
1924	87,926,862
1925	61,817,149
1926	84,437,452
1927	80,095,564
1928	75,348,069
1929	73,828,195
1930	69,384,837
1931	59,645,652
1932	49,855,221
1933	49,541,344
1934	57,168,291
1935	52,158,783
1936	54,579,535
1937	51,856,433
1938	46,099,027
1939	51,487,377
1940	51,484,640
1941	56,368,267

NOTE: Beginning with 1930 anthracite production was greater than the above figures by the amounts mined by bootleg coal operators but not reported.

SOURCES: Years 1769-1875, Howard N. Eavenson, *The First Century and a Quarter of American Coal Industry,* p. 498. Years 1876-1931, *Mineral Resources of the United States.* Years 1932 to date, *Minerals Yearbook.*

TABLE 3. ANTHRACITE PRODUCTION IN PENNSYLVANIA BY COUNTIES

Year	Berks County[1]		Carbon County		Columbia County		Dauphin County	
	Net tons[2]	Value[2]	Net tons	Value	Net tons	Value	Net tons	Value
1922	66,080	$133,000	1,891,680	$8,920,000	442,400	$1,906,000	1,066,240	$3,363,000
1923	47,040	79,000	3,170,600	15,696,000	1,208,480	5,386,000	1,459,360	5,873,000
1924	73,920	73,000	2,647,680	14,043,000	697,760	3,043,000	1,450,400	5,826,000
1925	71,680	96,000	1,914,080	9,645,000	412,160	1,868,000	1,083,040	3,975,000
1926	38,080	67,000	2,576,000	13,264,000	738,080	3,675,000	1,344,000	5,694,000
1927	246,400	257,000	2,498,720	12,238,000	660,800	3,009,000	1,383,200	5,330,000
1928	241,920	270,000	1,902,880	9,182,000	540,960	2,152,000	1,155,840	4,448,000
1929	212,800	221,000	1,999,200	9,826,000	367,360	1,698,000	1,133,440	4,675,000
1930	147,000	150,000	1,662,000	7,930,000	279,000	1,343,000	1,008,000	4,194,000
1931	92,000	106,000	1,729,000	7,964,000	346,000	1,668,000	970,000	3,850,000
1932	94,000	135,000	1,662,000	6,814,000	215,000	890,000	800,000	3,001,000
1933	107,000	128,000	1,632,000	6,491,000	559,000	2,236,000	765,000	2,783,000
1934	117,000	143,000	2,037,000	8,476,000	198,000	798,000	835,000	2,811,000
1935	112,000	125,000	1,536,000	5,926,000	222,000	898,000	642,000	2,096,000
1936	105,000	112,000	1,827,000	7,607,000	913,000	3,503,000	506,000	1,700,000
1937	89,000	99,000	1,867,000	7,123,000	726,000	2,634,000	753,000	1,926,000
1938	111,000	122,000	1,811,000	7,010,000	887,000	3,383,000	466,000	1,650,000
1939	105,000	119,000	2,176,000	7,705,000	245,000	830,000	[3] 583,000	[3] 1,977,000
1940	99,000	112,000	2,514,000	10,003,000	306,000	1,195,000	[3] 717,000	[3] 2,255,000
1941	264,000	334,000	2,775,000	11,847,000	285,000	1,197,000	[3] 760,000	[3] 2,416,000

Year	Lackawanna County		Luzerne County		Northumberland County		Schuylkill County	
	Net tons	Value	Net tons	Value	Net tons	Value	Net tons	Value
1922	11,282,880	$60,683,000	20,955,200	$111,339,000	4,263,840	$19,583,000	13,975,360	$64,461,000
1923	20,659,520	119,417,000	35,835,520	202,140,000	6,940,640	34,376,000	22,580,320	116,416,000
1924	20,092,800	113,025,000	34,812,960	198,381,000	6,806,240	33,418,000	20,147,680	103,242,000
1925	13,706,560	77,441,000	24,364,480	138,129,000	5,122,880	23,885,000	14,455,840	69,991,000
1926	18,979,520	112,487,000	33,536,160	197,662,000	6,351,520	33,168,000	19,559,680	102,055,000
1927	16,754,080	95,286,000	31,698,240	178,342,000	7,092,960	32,624,000	18,866,400	89,224,000
1928	16,347,520	91,458,000	29,514,240	164,234,000	6,679,680	30,229,000	18,301,920	88,376,000
1929	17,217,760	95,053,000	29,289,120	161,496,000	6,064,800	27,810,000	16,938,880	81,850,000
1930	15,141,000	82,930,000	27,809,000	149,407,000	6,988,000	31,449,000	15,949,000	75,151,000
1931	12,644,000	67,778,000	23,743,000	124,619,000	6,083,000	26,745,000	13,423,000	60,674,000
1932	11,569,000	55,089,000	19,699,000	92,141,000	4,327,000	16,322,000	11,021,000	45,772,000
1933	11,206,000	49,058,000	19,475,000	85,570,000	5,330,000	19,137,000	9,964,000	39,123,000
1934	12,188,000	55,948,000	21,455,000	95,340,000	6,026,000	23,257,000	13,455,000	53,807,000
1935	10,816,000	45,996,000	21,231,000	89,998,000	5,634,000	19,959,000	11,259,000	42,416,000
1936	11,161,000	49,164,000	20,854,000	92,311,000	5,403,000	20,170,000	13,295,000	50,545,000
1937	8,833,000	35,334,000	22,567,000	90,874,000	4,734,000	16,942,000	12,080,000	42,137,000
1938	8,119,000	33,362,000	19,928,000	82,534,000	4,253,000	15,524,000	10,288,000	36,317,000
1939	8,718,000	33,176,000	23,346,000	88,794,000	5,130,000	17,429,000	10,986,000	36,432,000
1940	8,667,000	36,066,000	22,157,000	94,425,000	5,200,000	18,493,000	11,619,000	42,216,000
1941	8,531,000	38,403,000	23,835,000	109,816,000	5,670,000	21,965,000	14,061,000	53,669,000

TABLE 3. ANTHRACITE PRODUCTION IN PENNSYLVANIA BY COUNTIES—Continued

Year	*Sullivan County*		*Susquehanna and Wayne Counties*		*Other Counties*[2]		*Total*	
	Net tons	*Value*	*Net tons*	*Value*	*Net tons*	*Value*	*Net tons*	*Value*
1922	277,760	$1,201,000	[4] 327,040	[4] $1,912,000	134,400	$199,000	54,683,022	$273,700,000
1923	329,280	1,978,000	943,040	5,284,000	165,760	142,000	93,339,009	506,787,000
1924	191,520	871,000	1,005,760	5,309,000	....	....	87,926,862	477,231,000
1925	142,240	642,000	([5])	([5])	544,320	1,993,000	61,817,149	327,665,000
1926	277,760	1,296,000	848,960	4,612,000	187,160	184,000	84,437,452	474,164,000
1927	169,240	638,000	724,640	3,994,000	....	....	80,095,564	420,942,000
1928	154,560	634,000	508,480	2,655,000	....	....	75,348,069	393,638,000
1929	123,200	578,000	481,600	2,436,000	....	....	73,828,195	385,643,000
1930	64,000	342,000	338,000	1,678,000	....	....	69,384,837	354,574,000
1931	57,000	305,000	558,000	2,646,000	....	....	59,645,652	296,355,000
1932	88,000	371,000	380,000	1,840,000	....	....	49,855,221	222,375,000
1933	113,000	367,000	392,000	1,826,000	....	....	49,541,344	206,718,000
1934	191,000	555,000	665,000	3,018,000	....	....	57,168,291	244,152,000
1935	190,000	603,000	516,000	2,116,000	....	....	52,158,783	210,131,000
1936	219,000	628,000	297,000	1,264,000	....	....	54,579,535	227,004,000
1937	89,000	217,000	120,000	314,000	....	....	51,856,433	197,599,000
1938	49,000	122,000	187,000	576,000	....	....	46,099,027	180,600,000
1939	37,000	96,000	163,000	617,000	....	....	51,487,377	187,175,000
1940	51,000	122,000	155,000	603,000	....	....	51,484,640	205,490,000
1941	37,000	83,000	[6] 152,000	[6] 545,000	....	....	56,368,267	240,275,000

[1] Dredge or river coal.

[2] Other counties included with Berks County in 1927 and subsequent years.

[3] Includes Lebanon County.

[4] Wayne County only.

[5] Included in other counties.

[6] Includes Snyder County.

Culm Bank
by M. J. Gallagher

TABLE 4. COAL RECLAIMED FROM STREAMS IN PENNSYLVANIA, BY COUNTIES
(Net tons)

Year	*Berks*	*Carbon*	*Columbia*	*Dauphin*	*Lancaster*	*Lebanon*
1921	23,439	...	5,535	277,477	29,702	...
1922	58,420	...	11,865	486,925	62,019	...
1923	30,248	...	7,092	514,939	74,097	...
1924	21,027	...	6,904	403,603	62,276	935
1925	54,863	...	11,949	344,113	73,627	5,181
1926	21,925	...	7,953	358,229	65,252	4,560
1927	27,256	...	...	358,253	78,459	7,996
1928	19,674	...	16,089	265,856	71,303	14,880
1929	24,438	...	16,949	297,992	42,856	12,799
1930	25,626	...	8,537	196,587	81,284	12,751
1931	15,368	...	13,823	199,216	90,477	7,394
1932	10,891	...	17,430	141,729	42,804	3,519
1933	11,305	...	14,502	154,434	59,880	2,967
1934	9,117	...	15,399	208,200	54,188	...
1935	22,033	39,616	18,933	175,091	39,562	3,192
1936	6,204	21,337	41,781	185,531	35,897	3,906
1937	16,217	10,900	20,862	315,306	49,171	5,074
1938	14,917	28,875	19,353	183,901	36,869	4,613
1939	14,084	17,877	27,682	196,952	49,600	5,732
1940	10,037	21,254	28,155	280,443	44,555	4,180
1941	7,807	26,530	18,009	267,082	40,238	6,547

Year	*Luzerne*	*Montour*	*Northampton*	*Northumberland*	*Schuylkill*	*York*	*Total*
1921	28,652	650	...	115,702	82,114	...	563,271
1922	111,030	3,083	...	119,962	140,182	...	993,486
1923	178,898	1,344	38,220	267,108	64,045	...	1,175,991
1924	15,663	1,141	26,111	227,424	63,632	26,359	855,075
1925	72,344	1,949	40,517	174,495	74,598	33,314	886,950
1926	28,092	2,262	41,432	159,298	113,514	35,887	838,404
1927	...	1,008	32,942	213,503	68,068	41,702	829,187
1928	23,451	2,128	32,272	246,189	127,785	24,892	844,519
1929	...	2,184	27,409	104,476	112,517	26,449	668,069
1930	...	2,296	15,327	60,857	92,956	22,414	518,635
1931	...	1,200	...	20,380	74,163	17,629	439,650
1932	...	1,600	13,440	35,101	91,482	17,500	375,496
1933	17,900	...	...	47,044	96,025	17,920	421,977
1934	17,000	...	...	46,549	121,886	14,436	486,775
1935	19,000	...	14,000	55,531	102,013	15,000	503,971
1936	20,410	...	14,878	38,659	164,754	18,876	552,233
1937	27,527	...	...	39,985	174,418	21,375	680,835
1938	27,185	...	13,769	38,367	141,357	21,814	531,020
1939	16,760	...	12,300	31,911	192,279	20,117	585,294
1940	6,300	...	...	35,100	157,406	19,808	607,238
1941	5,945	...	...	42,069	153,686	12,055	579,968

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

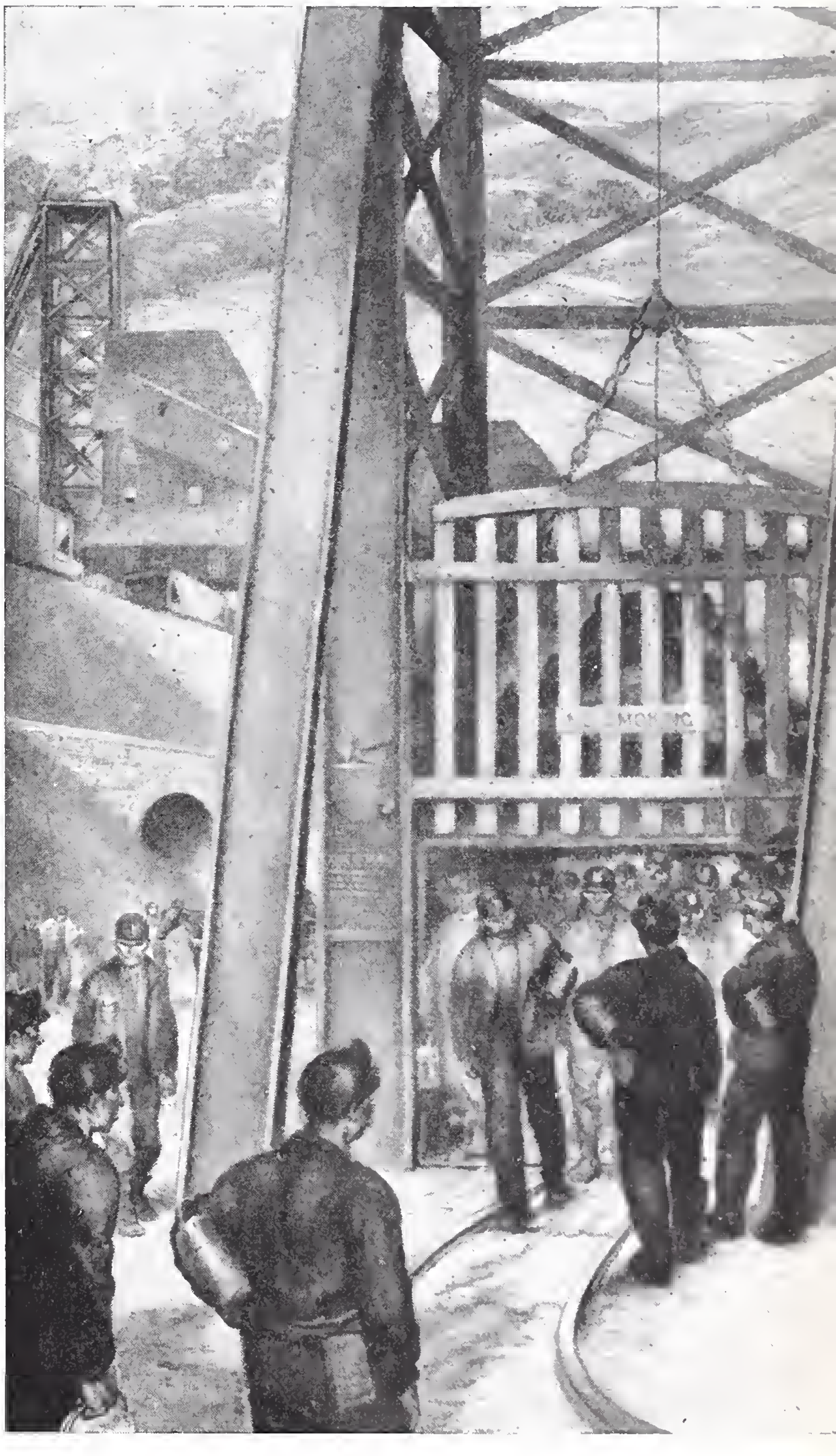
BITUMINOUS COAL

Pennsylvania possesses no such monopoly in the production and marketing of bituminous coal as it does in the case of anthracite. As bituminous coal is widely distributed in many of our States, this Pennsylvania industry is constantly facing competition, not only from other sources of energy but from bituminous coal produced elsewhere. In 1850, production amounted to about 2 million tons. Since that time expansion has been fairly regular and a peak production of over 178 million tons was reached in 1918. This abnormal demand resulted in an increased capacity for production which became a serious problem in consequence of the diminished demands of later years. Pennsylvania has also lost its position of the country's leading producer, having been passed by West Virginia in 1927. In 1929 and 1930, Pennsylvania again held first rank, but since that time has had to be content with second rank.

The stimulation in demand due to the present war has not resulted in annual tonnage production equal to the last war. The decrease in the demand for our bituminous coal is due to the increase in production in nearby States, particularly West Virginia, Illinois, and Kentucky, and to greater economies in the combustion of fuel.

The figures here given form two tables. In the first, extending from 1759 to date, the figures up to and including 1880 are taken direct and in toto from H. N. Eavenson's book (pages 485-490). Note however: (1) That the Pittsburgh bed in Allegheny, Fayette, Washington and Westmoreland Counties is not differentiated by county, that estimates of production from other beds are given for Westmoreland County, but not for the others. (2) That figures for Centre County cover only the Snowshoe field. Possibly coal from other parts of the county are included with Clearfield County. (3) That only one set of figures is given for the Broadtop field, covering parts of Huntingdon, Bedford and Fulton Counties. It is believed that these figures are the most reliable data obtainable.

The second table, including the years from 1881 to 1942, has been derived from the mineral resource reports of the United States Geological Survey and United States Bureau of Mines. To make the tables complete, estimates are given for the years 1881, 1882 and 1883. These were obtained by assuming equal increases (or decreases) between the Eavenson figures for 1880 and the United States Geological Survey figures for 1884. Thus for Blair County the total difference was roundly 24,000 tons, or 6,000 tons gain each year. In other instances the change was a graduated decrease. Where figures for two or more counties were previously combined, the ratio of production for 1884 is presumed to have held for the three preceding years and the estimated production for those years is so allotted as to meet that ratio and still add up to the total for the year as given in the official government estimate.



Changing Shift
by Edmund M. Ashe

The River Boat
by Ruby Glasser Shilliday

TABLE 5. BITUMINOUS COAL PRODUCED IN PENNSYLVANIA

Year	*Net tons*
1759	50
1760	50
1761	100
1762	100
1763	100
1764	100
1765	100
1766	100
1767	100
1768	100
1769	100
1770	100
1771	100
1772	100
1773	100
1774	100
1775	150
1776	150
1777	150
1778	200
1779	200
1780	400
1781	600
1782	800
1783	1,000
1784	3,000
1785	5,000
1786	10,000
1787	15,000
1788	20,000
1789	25,000
1790	30,000
1791	34,000
1792	38,000
1793	42,000
1794	46,000
1795	50,000
1796	57,000
1797	64,000
1798	71,000
1799	79,000
1800	87,000
1801	89,000
1802	92,000
1803	94,000
1804	97,100
1805	100,100
1806	104,200
1807	108,200
1808	112,300
1809	116,600
1810	120,700
1811	130,800
1812	143,000
1813	155,100
1814	169,300
1815	183,600
1816	205,900
1817	228,000
1818	251,300
1819	232,900
1820	225,600
1821	233,900
1822	243,000
1823	251,200
1824	260,400
1825	270,050
1826	294,680
1827	320,850
1828	347,500
1829	372,100
1830	397,700
1831	425,340
1832	450,940
1833	437,240
1834	504,540
1835	531,640
1836	607,420
1837	575,260
1838	618,263
1839	731,322
1840	699,994
1841	783,515
1842	833,900
1843	887,100
1844	981,500
1845	1,130,000
1846	1,255,500
1847	1,466,900
1848	1,767,300
1849	1,952,500
1850	2,147,500
1851	2,403,300
1852	2,719,200
1853	2,944,800
1854	3,230,800
1855	3,429,700
1856	3,695,786
1857	4,335,039
1858	4,383,560
1859	4,504,000
1860	4,710,400
1861	4,562,000
1862	4,995,600
1863	5,332,600
1864	6,051,600
1865	6,372,900
1866	6,512,300
1867	6,441,800
1868	7,348,400
1869	8,878,000
1870	9,223,856
1871	12,023,130
1872	12,920,876
1873	13,787,700
1874	12,559,800
1875	12,443,860
1876	12,282,000
1877	14,000,000
1878	15,120,000
1879	16,240,000
1880	21,280,000
1881	22,400,000
1882	24,640,000
1883	26,880,000
1884	28,000,000
1885	26,000,000
1886	27,094,501
1887	31,516,856
1888	33,796,727
1889	36,174,091
1890	42,302,173
1891	42,788,490
1892	46,694,576
1893	44,070,724
1894	39,912,463
1895	50,217,228
1896	49,557,453
1897	54,597,891
1898	65,165,133
1899	74,150,175
1900	79,842,326
1901	82,305,946
1902	98,574,367
1903	103,117,178
1904	97,938,287
1905	118,413,637
1906	129,293,206
1907	150,143,177
1908	117,179,527
1909	137,966,791
1910	150,521,526
1911	144,561,257
1912	161,865,488
1913	173,781,217
1914	147,983,294
1915	157,955,137
1916	170,295,424
1917	172,448,142
1918	178,550,741
1919	150,758,154
1920	170,607,847
1921	116,013,942
1922	113,148,308
1923	171,879,913
1924	130,633,773
1925	136,928,019
1926	153,041,638
1927	132,964,639
1928	131,202,163
1929	143,516,241
1930	124,462,787
1931	97,658,698
1932	74,775,862
1933	79,295,944
1934	89,825,875
1935	91,404,670
1936	109,887,470
1937	111,002,289
1938	77,704,537
1939	92,584,113
1940	116,602,999
1941	130,240,000
1942	143,174,000

NOTE: Total production for the years 1759 to 1789 inclusive has been estimated by Howard N. Eavenson in a later report (1942) at 200,000 net tons.

SOURCES: Years 1759-1789, Eavenson, *Pittsburgh Coal Bed.* Years 1790-1880, Eavenson, *First Century and a Quarter of American Coal Industry.* Years 1881-1931, *Mineral Resources of the United States.* Years 1932 to date, *Minerals Yearbook.*

TABLE 6. BITUMINOUS COAL PRODUCTION IN PENNSYLVANIA BY COUNTIES
(Net tons)

County	*1881* [1]	*1882* [1]	*1883* [1]	*1884*	*1885*
Allegheny	3,029,000	2,968,000	2,915,000	2,863,631	3,588,244
Armstrong	245,000	220,000	195,000	170,826	139,327
Beaver	147,000	150,000	153,000	156,695	184,631
Bedford	130,000	110,000	90,000	69,770	107,694
Blair	190,000	196,000	202,000	208,541	205,075
Bradford	454,000	407,000	360,000	313,575	249,920
Butler	51,000	84,000	117,000	151,335	85,429
Cambria	780,000	740,000	700,000	659,843	1,037,000
Cameron	87,000	62,000	38,000	13,652	7,706
Centre	114,000	148,000	182,000	216,422	373,504
Clarion	565,000	480,000	415,000	329,973	299,216
Clearfield	1,853,000	1,961,000	2,069,000	2,177,543	3,368,671
Elk	338,000	363,000	388,000	413,243	537,826
Fayette	4,310,000	4,218,000	4,130,000	4,041,643	3,192,972
Greene	....	....	....	....	8,248
Huntingdon	390,000	330,000	271,000	212,527	247,424
Indiana	52,000	45,000	38,000	30,758	82,750
Jefferson	420,000	430,000	440,000	450,079	479,675
Lawrence	178,000	133,000	87,000	42,818	42,137
Lycoming	236,922	209,838	184,552	....	....
McKean	110,000	73,834	84,899	78,870	44,312
Mercer	433,000	381,000	329,000	276,350	378,508
Somerset	298,000	289,000	280,000	269,930	302,715
Tioga	1,178,381	1,165,604	1,217,870	931,922	1,067,081
Venango	11,000	12,000	13,000	15,000	7,000
Washington	737,000	741,000	724,000	707,262	836,633
Westmoreland	3,553,000	3,477,000	3,379,000	3,282,733	3,774,072
Total [2]	19,890,303	19,394,276	19,002,321	18,084,941	20,647,770

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[1] Official figures are not available for 1881, 1882 and 1883. They have been estimated by adding or subtracting increments to Eavenson's figures for 1880 to increase or decrease the production to the 1884 figures. Where Eavenson's 1880 figures are combined, the ratios of the counties in the 1884 figures had been used. Thus in 1884 the Broadtop field yielded 282,297 tons. In 1884 the railroad known as the Clearfield-Tyrone Branch carried over 3 million tons.

[2] The totals for 1881-1885 do not allow for unreported coal, which has been estimated at from 2,500,000 tons in 1881 to as high as 10,000,000 tons in 1884.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1886*	*1887*	*1888*	*1889*	*1890*
Allegheny	4,202,086	4,680,924	5,575,505	4,717,431	4,894,372
Armstrong	210,856	235,221	226,093	289,218	380,554
Beaver	208,820	197,863	63,900	93,461	139,117
Bedford	173,372	311,452	248,159	257,455	445,192
Blair	305,695	287,367	314,013	215,410	298,196
Bradford	206,998	167,416	163,851	129,141	126,687
Butler	162,306	161,764	194,715	288,591	167,578
Cambria	1,222,028	1,421,980	1,540,460	1,751,664	2,790,954
Cameron	3,200	3,000	700	2,300	....
Centre	313,383	508,255	382,770	395,127	452,114
Clarion	429,544	593,758	535,192	596,589	512,387
Clearfield	3,753,986	5,180,311	5,398,981	5,224,506	6,651,587
Clinton	....	....	32,000	106,000	159,000
Elk	526,036	609,757	555,960	614,113	1,121,534
Fayette	4,494,613	4,540,322	5,208,993	5,897,254	6,413,081
Greene	5,600	3,002	5,323	53,714	([1])
Huntingdon	313,581	265,479	281,823	280,133	322,630
Indiana	103,615	207,597	157,285	153,698	357,580
Jefferson	1,023,186	1,693,492	2,275,349	2,896,487	2,850,799
Lawrence	101,154	125,361	106,921	143,410	140,528
McKean	617	9,214	10,443	11,500	([1])
Mercer	537,712	539,721	487,122	575,751	524,319
Somerset	349,926	416,240	370,228	442,027	522,796
Tioga	1,384,800	1,328,963	1,106,146	1,036,175	903,997
Venango	2,500	2,296	2,000	6,911	([1])
Washington	1,612,407	1,751,615	1,793,022	2,364,901	2,836,667
Westmoreland	5,446,480	6,074,486	6,519,773	7,631,124	8,290,504
Small mines	....	200,000	240,000	([2])	1,000,000
Total	27,094,501	31,516,856	33,796,727	36,174,091	42,302,173

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[1] Included in small mines.

[2] Included in county distribution.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1891*	*1892*	*1893*	*1894*	*1895*
Allegheny	5,640,669	6,399,199	6,663,095	6,354,559	6,615,974
Armstrong	484,000	583,519	561,039	580,030	642,809
Beaver	129,961	140,835	150,095	103,765	184,096
Bedford	389,257	552,461	501,507	313,095	417,988
Blair	237,626	259,224	177,902	256,157	374,157
Bradford	68,697	57,708	42,739	28,027	52,711
Butler	211,647	145,729	156,016	137,593	233,104
Cambria	2,932,973	3,086,554	3,282,467	2,978,927	4,289,257
Centre	526,753	496,521	458,056	307,806	273,647
Clarion	479,887	569,333	551,158	401,004	389,850
Clearfield	7,143,382	6,876,785	6,148,758	4,148,464	5,215,527
Clinton	130,802	98,242	94,582	100,000	95,291
Elk	973,600	731,575	634,165	399,023	642,143
Fayette	5,782,573	7,260,044	6,261,146	6,440,989	9,665,369
Huntingdon	269,021	333,855	303,547	[1] 200,155	327,770
Indiana	456,077	514,463	380,666	398,548	513,075
Jefferson	3,160,614	3,706,329	3,885,196	3,248,154	4,248,329
Lawrence	164,669	216,561	196,736	132,422	269,779
Lycoming		20,515	53,192	80,160	84,050
McKean	15,345	21,282	19,169	19,844	38,000
Mercer	526,220	420,145	499,651	331,594	535,042
Somerset	480,194	509,610	532,688	418,195	524,755
Tioga	1,010,872	999,784	962,248	704,560	801,091
Washington	2,606,158	2,903,235	3,315,146	3,461,428	3,577,260
Westmoreland	7,967,493	8,791,068	7,439,760	7,767,964	9,606,154
Small mines	1,000,000	1,000,000	800,000	600,000	600,000
Total	42,788,490	46,694,576	44,070,724	39,912,463	50,217,228

[1] Includes coal produced in Forest County.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1896*	*1897*	*1898*	*1899*	*1900*
Allegheny	7,856,867	7,216,039	8,889,997	9,972,060	10,051,905
Armstrong	614,932	857,637	818,404	1,054,389	1,313,188
Beaver	127,290	99,546	223,855	258,466	262,398
Bedford	237,414	436,619	456,507	493,965	570,055
Blair	360,987	492,975	404,043	407,356	496,992
Bradford	53,519	41,588	22,508	31,835	32,065
Butler	230,336	233,689	161,312	214,899	221,704
Cambria	4,649,819	5,416,950	6,740,461	7,208,834	8,190,366
Centre	251,665	521,100	714,175	912,648	932,265
Clarion	371,749	247,839	278,131	289,753	404,639
Clearfield	4,812,017	5,479,047	6,055,739	6,251,442	6,620,834
Clinton	134,569	157,333	166,250	221,574	288,881
Elk	807,886	969,503	873,485	1,221,979	926,403
Fayette	8,076,200	9,701,691	12,696,063	14,609,289	15,055,242
Huntingdon	339,597	303,939	312,607	357,812	368,942
Indiana	418,642	541,967	563,791	616,911	924,782
Jefferson	4,508,077	4,697,059	5,625,168	5,841,960	6,199,290
Lawrence	198,666	195,286	185,408	183,555	187,810
Lycoming	83,230	91,735	98,118	101,923	99,000
McKean	33,133	31,527	25,622	23,703	20,214
Mercer	579,069	435,772	316,669	486,724	528,070
Somerset	787,050	924,607	1,846,398	2,950,343	4,779,307
Sullivan	....	179,917		....	....
Tioga	825,687	938,053	921,760	670,126	931,301
Washington	4,039,976	3,862,661	4,753,673	4,987,360	4,856,138
Westmoreland	8,559,076	9,923,812	11,414,989	14,181,269	14,980,535
Small mines	600,000	600,000	600,000	600,000	600,000
Total	49,557,453	54,597,891	65,165,133	74,150,175	79,842,326

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1901*	*1902*	*1903*	*1904*	*1905*
Allegheny	10,307,100	11,919,569	12,689,225	12,291,261	13,496,214
Armstrong	1,555,255	1,793,179	1,920,584	1,996,661	2,497,314
Beaver	176,012	225,162	180,102	67,923	82,676
Bedford	500,322	797,248	926,334	540,850	752,715
Blair	368,779	338,204	309,736	244,932	348,749
Bradford	22,189	....	....		
Butler	269,161	454,166	649,033	497,316	550,589
Cambria	9,045,201	10,561,835	10,942,496	10,845,560	12,600,891
Centre	839,512	1,000,598	759,458	712,036	810,441
Clarion	354,840	458,221	531,630	551,532	714,478
Clearfield	5,886,407	7,334,785	7,462,682	5,746,870	7,248,305
Clinton	306,228	365,732	403,543	341,967	296,988
Elk	1,007,314	756,182	1,339,281	1,129,231	1,249,337
Fayette	16,187,224	18,988,058	19,613,161	19,231,011	24,250,989
Greene	....	25,550	153,000	80,646	105,000
Huntingdon	374,529	460,485	500,647	487,223	559,039
Indiana	1,074,260	1,655,281	2,043,140	2,683,951	4,477,431
Jefferson	5,806,568	6,083,494	6,474,764	6,043,564	6,393,985
Lawrence	171,959	212,445	232,992	182,662	267,470
Lycoming	107,095	112,820	57,030	78,837	33,844
Mercer	577,338	628,713	704,747	619,648	707,964
Somerset	4,831,660	5,911,326	5,957,751	5,317,161	6,412,672
Tioga	861,072	1,149,849	905,688	616,828	706,723
Washington	5,910,621	8,529,954	9,216,267	8,900,254	10,762,627
Westmoreland	15,165,300	18,811,511	19,127,904	18,688,974	23,011,546
Small mines	600,000	(1)	[2] 15,983	[2] 41,389	[2] 75,650
Total	82,305,946	98,574,367	103,117,178	97,938,287	118,413,637

[1] Small mines in county production.

[2] Includes production of Cameron County.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1906*	*1907*	*1908*	*1909*	*1910*
Allegheny	16,823,027	18,315,736	14,083,843	16,087,010	18,835,336
Armstrong	2,574,758	3,430,002	2,777,486	2,787,508	3,304,915
Beaver	81,531	109,575	222,711	224,450	228,226
Bedford	734,855	967,313	511,014	435,129	716,833
Blair	402,438	493,219	315,167	410,161	380,870
Butler	803,499	902,729	802,462	828,043	1,017,809
Cambria	12,439,152	16,361,880	14,138,308	15,545,185	16,629,461
Centre	895,434	1,256,383	1,086,384	1,239,049	1,293,622
Clarion	719,548	1,078,367	972,785	941,059	1,156,697
Clearfield	5,944,745	8,034,711	6,247,534	7,573,322	8,463,910
Clinton	233,674	322,624	253,958	272,184	310,973
Elk	944,367	1,427,841	1,147,209	1,150,675	1,202,323
Fayette	27,044,451	29,260,622	19,474,417	28,866,229	31,097,233
Greene	144,251	158,187	145,644	137,448	77,321
Huntingdon	630,155	721,604	598,094	502,823	669,226
Indiana	4,657,457	7,635,998	6,843,179	7,681,205	8,954,366
Jefferson	5,160,195	5,964,397	4,853,313	4,934,907	5,668,883
Lawrence	257,716	220,718	142,639	156,749	95,102
Lycoming	44,425	51,956	34,626	28,016	25,725
Mercer	842,648	955,290	724,158	893,880	867,754
Somerset	6,674,191	7,769,708	7,404,945	7,902,338	8,837,682
Tioga	826,925	1,146,353	682,099	785,922	1,037,417
Washington	12,714,405	14,535,727	12,118,007	12,982,179	16,638,677
Westmoreland	27,573,420	28,916,721	21,499,292	25,432,320	22,885,404
Small mines	[1] 125,939	[2] 105,516	[3] 100,253	[4] 169,000	125,761
Total	129,293,206	150,143,177	117,179,527	137,966,791	150,521,526

[1] Includes production of Cameron County.

[2] Includes production of Cameron, Bradford and McKean Counties.

[3] Includes production of Bradford County.

[4] Includes production of Bradford and Cameron Counties.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1911*	*1912*	*1913*	*1914*	*1915*
Allegheny	17,863,795	18,867,265	20,117,823	16,808,202	17,417,815
Armstrong	3,799,227	4,104,989	5,321,622	4,579,389	5,159,882
Beaver	203,556	247,465	248,585	101,809	87,891
Bedford	528,170	731,477	850,792	634,219	635,791
Blair	294,048	324,336	391,717	308,945	308,541
Bradford	....	....	...	[1] 36,374	[1] 50,904
Butler	957,074	1,000,947	1,080,002	981,704	1,036,877
Cambria	16,928,628	17,585,130	19,621,378	18,034,487	18,716,451
Centre	1,140,263	1,291,374	1,497,271	1,264,075	1,430,749
Clarion	1,057,390	1,199,322	1,427,848	1,341,392	1,291,119
Clearfield	7,852,426	7,938,337	8,278,015	7,149,023	8,022,894
Clinton	314,643	345,454	343,054	326,545	359,275
Elk	1,223,856	1,146,496	1,201,065	963,238	1,045,554
Fayette	26,610,162	32,366,567	32,607,963	23,336,180	28,424,067
Greene	31,743	35,839	316,752	290,497	546,008
Huntingdon	806,199	834,914	935,774	851,128	1,010,750
Indiana	8,780,983	9,174,927	10,204,684	9,422,996	9,553,857
Jefferson	5,550,816	5,416,536	5,801,864	5,089,623	4,895,409
Lawrence	90,151	75,823	94,283	123,987	131,746
Lycoming	13,271	7,777	26,953	....	....
Mercer	859,355	846,228	777,601	716,995	694,411
Somerset	9,177,421	9,888,144	9,928,776	10,238,763	10,343,369
Tioga	830,330	997,787	943,748	679,221	788,003
Washington	15,343,772	16,645,127	18,309,317	15,495,674	15,898,719
Westmoreland	24,102,195	30,589,549	33,258,702	28,995,427	29,892,561
Small mines	[2] 201,783	[3] 203,678	[4] 195,628	172,863	165,483
Cameron and McKean	....	....	...	40,538	47,011
Total	144,561,257	161,865,488	173,781,217	147,983,294	157,955,137

[1] Includes Lycoming County.

[2] Includes Bradford, Cameron and McKean Counties.

[3] Includes Fulton, Cameron and McKean Counties.

[4] Includes Cameron and McKean Counties.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1916*	*1917*	*1918*	*1919*	*1920*
Allegheny	17,007,431	17,836,377	17,375,035	14,856,781	16,047,575
Armstrong	5,430,188	5,574,861	6,051,753	4,665,232	5,975,063
Beaver	91,553	129,163	128,572	139,294	170,900
Bedford	721,587	947,053	1,050,528	704,289	785,903
Blair	435,792	271,598	279,817	181,209	158,257
Bradford and Lycoming	39,005	47,151	31,299	13,373	[1] 67,932
Butler	1,180,008	1,201,963	1,397,927	1,128,192	1,542,307
Cambria	19,588,350	19,730,770	20,569,253	16,899,818	18,967,754
Centre	1,819,007	1,999,407	1,984,664	1,296,061	1,735,045
Clarion	1,368,544	1,380,494	1,607,641	1,393,647	1,567,095
Clearfield	8,876,823	9,336,533	9,376,429	7,573,392	9,242,416
Clinton	422,062	401,812	360,123	288,100	327,296
Elk	937,583	907,187	968,868	947,595	1,258,834
Fayette	34,249,848	32,083,027	32,925,888	29,660,105	30,742,236
Greene	744,860	900,378	1,269,425	1,423,118	2,078,835
Huntingdon	962,332	1,155,602	1,371,562	833,690	839,613
Indiana	11,022,780	12,053,766	12,743,190	8,526,404	11,414,048
Jefferson	5,764,525	5,551,658	5,140,833	3,841,478	5,346,458
Lawrence	....	132,929	107,086	140,054	157,934
McKean and Cameron	28,859	12,165	7,483	....	....
Mercer	[3] 614,994	527,421	690,785	481,521	530,427
Somerset	9,340,568	9,454,537	10,264,083	10,433,752	10,532,967
Tioga	829,561	866,803	834,385	593,637	763,611
Washington	18,119,353	21,513,603	23,537,263	19,515,856	23,321,195
Westmoreland	30,499,703	28,027,782	28,121,234	24,947,773	24,510,146
Small mines	200,108	[2] 404,102	[2] 355,615	[2] 273,783	2,524,000
Wagon mines served by rail	....	....	....	....	....
Total	170,295,424	172,448,142	178,550,741	150,758,154	170,607,847

[1] Includes Fulton County in 1920 and 1921; also McKean County in 1921.

[2] Includes Fulton County in 1917 and 1918; Fulton and McKean Counties in 1919.

[3] Includes Lawrence County.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1921*	*1922*	*1923*	*1924*	*1925*
Allegheny	11,931,527	11,023,211	20,224,239	14,497,825	12,002,358
Armstrong	3,388,762	3,265,848	5,061,732	3,633,619	3,180,037
Beaver	161,409	226,959	247,071	236,763	314,510
Bedford	317,244	340,434	597,496	280,193	442,693
Blair	92,144	98,206	169,276	71,687	[3]222,258
Bradford and Lycoming	[4]55,296	[5]7,904	[5]10,330	[5]4,153	35,285
Butler	923,391	1,837,961	1,856,319	1,352,354	1,996,562
Cambria	16,339,228	12,957,315	19,751,465	16,639,668	17,326,515
Centre	764,994	1,207,859	1,356,503	814,696	1,019,955
Clarion	1,248,294	1,320,469	1,900,549	1,298,387	1,515,262
Clearfield	5,853,922	5,456,359	7,546,058	5,311,004	5,586,284
Clinton	83,641	146,150	260,551	299,926	188,813
Elk	878,201	855,105	1,147,125	1,137,569	1,038,634
Fayette	19,260,778	17,759,776	32,165,961	25,432,133	28,819,108
Greene	2,294,801	2,348,527	3,982,003	3,747,529	5,185,965
Huntingdon	484,008	397,150	757,678	763,857	673,203
Indiana	6,357,971	7,620,831	10,475,299	7,042,584	8,308,679
Jefferson	2,707,894	2,900,435	4,381,693	2,944,076	2,990,465
Lawrence	193,657	208,907	281,708	234,163	241,769
McKean	(1)	....	....	....	[7]12,527
Mercer	479,887	457,453	465,349	300,069	276,486
Somerset	8,975,809	7,628,253	8,530,618	8,436,736	9,450,958
Tioga	437,702	374,154	480,335	293,098	198,114
Washington	14,716,984	12,572,477	24,499,103	17,937,840	15,274,447
Westmoreland	18,066,398	20,639,693	25,408,870	17,802,651	20,627,132
Other counties	....	....	[6]83,625	[6]121,193	....
Small mines	....	[2]50,682	....	....	....
Wagon mines served by rail	....	1,446,190	238,957	....	....
Total	116,013,942	113,148,308	171,879,913	130,633,773	136,928,019

[1] Includes Fulton County in 1920 and 1921 and McKean County in 1921.

[2] Cameron and McKean Counties.

[3] Includes Fulton County.

[4] Includes Fulton County in 1920 and 1921 and McKean County in 1921.

[5] Bradford County only.

[6] Cameron, Fulton, Lycoming and McKean Counties.

[7] Includes Venango County.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1926*	*1927*	*1928*	*1929*	*1930*
Allegheny	13,640,290	10,348,468	13,393,534	16,633,741	16,726,451
Armstrong	4,521,464	5,618,029	4,917,224	4,468,034	3,530,621
Beaver	323,562	297,634	268,819	151,981	101,915
Bedford	605,210	497,407	513,357	569,932	404,342
Blair	[1] 352,788	[1] 301,956	[1] 327,374	[1] 386,645	251,272
Bradford and Lycoming	47,534	38,903	40,620	14,003	34,017
Butler	1,836,309	1,790,975	1,609,355	1,372,985	965,728
Cambria	18,860,645	14,562,378	15,012,504	17,514,931	15,864,835
Centre	1,249,344	967,764	860,421	818,831	718,950
Clarion	1,516,709	1,411,859	1,167,607	1,472,777	1,307,560
Clearfield	5,201,108	4,462,547	3,428,608	3,943,545	3,528,275
Clinton	269,904	257,305	246,132	183,918	73,528
Elk	813,856	770,824	835,698	1,012,303	951,309
Fayette	32,755,937	30,082,320	29,564,103	31,400,228	23,830,852
Greene	6,358,917	6,742,579	6,531,661	6,301,773	5,062,284
Huntingdon	651,731	331,220	336,381	529,119	520,213
Indiana	10,331,805	9,414,644	8,481,267	8,217,870	7,732,433
Jefferson	2,795,490	2,278,106	2,252,755	2,574,792	2,303,984
Lawrence	246,334	231,914	217,827	197,420	216,485
McKean and Venango	14,198	12,466	10,548	8,724	[1] 129,683
Mercer	344,647	303,780	282,510	247,700	218,510
Somerset	10,142,178	10,230,220	9,288,331	8,816,741	8,034,626
Tioga	188,759	156,819	110,224	163,967	181,894
Washington	17,881,410	12,029,128	14,776,269	19,327,687	17,560,396
Westmoreland	22,091,509	19,825,394	16,729,034	17,186,594	14,212,624
Total	153,041,638	132,964,639	131,202,163	143,516,241	124,462,787

[1] Includes production of Fulton County.

Table 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1931*	*1932*	*1933*	*1934*	*1935*
Allegheny	14,203,324	11,720,574	11,583,002	13,877,694	13,856,980
Armstrong	2,869,737	2,299,542	2,475,674	2,531,606	2,289,252
Beaver	85,953	63,424	84,348	94,860	83,655
Bedford	359,719	334,448	387,137	402,451	406,636
Blair	253,635	235,764	243,769	202,133	212,947
Bradford and Lycoming	36,043	39,315	....	....	....
Butler	670,981	503,562	566,028	675,092	687,023
Cambria	13,235,948	10,835,759	12,046,973	12,498,362	12,521,766
Centre	585,401	487,752	561,776	484,864	445,901
Clarion	1,143,744	1,109,698	1,179,623	1,305,763	1,245,156
Clearfield	3,101,586	2,588,444	2,773,841	3,072,532	2,980,476
Clinton	67,068	75,399	37,660	62,509	62,649
Elk	907,985	701,684	737,664	815,115	753,153
Fayette	13,938,055	8,374,764	10,075,860	11,927,582	13,456,428
Greene	3,677,945	3,170,954	2,742,216	3,754,179	3,488,767
Huntingdon	540,545	538,404	540,138	525,443	500,357
Indiana	6,803,084	4,951,488	5,102,427	6,189,751	5,618,534
Jefferson	2,014,943	1,688,051	1,659,757	1,805,300	1,846,945
Lawrence	203,402	118,052	171,789	199,901	179,127
Lycoming	....	....	40,066	54,212	58,124
Mercer	232,410	186,638	226,125	282,095	322,795
Somerset	7,401,426	5,529,311	5,487,877	5,918,908	5,700,742
Tioga	194,304	192,289	189,711	206,691	182,169
Washington	13,616,183	10,506,822	11,587,111	13,644,470	15,321,512
Westmoreland	11,361,881	8,337,969	8,589,286	9,075,415	8,990,487
Fulton, McKean and Venango	[2] 153,396	185,755	[1] 206,086	[1] 218,947	[1] 193,089
Total	97,658,698	74,775,862	79,295,944	89,825,875	91,404,670

[1] Includes production of Bradford County.

[2] Includes production of Cameron County.

TABLE 6. BITUMINOUS COAL PRODUCTION—Continued

County	*1936*	*1937*	*1938*	*1939*	*1940*
Allegheny	16,423,019	15,218,351	11,988,561	12,922,910	15,676,475
Armstrong	2,553,505	2,933,541	2,384,642	2,845,669	4,151,576
Beaver	136,815	134,976	416,292	664,275	706,955
Bedford	447,203	482,237	320,266	321,727	399,173
Blair	238,152	234,535	122,894	150,248	180,179
Butler	1,012,286	862,139	548,918	606,387	833,103
Cambria	14,469,001	14,818,927	12,333,025	13,784,840	16,386,244
Centre	535,177	537,308	323,712	426,383	668,799
Clarion	1,313,931	1,321,891	1,236,145	1,367,275	1,727,707
Clearfield	3,115,520	3,214,145	2,459,035	2,909,578	3,436,036
Clinton	57,141	48,767	33,564	41,740	50,467
Elk	769,016	605,837	634,837	[1] 824,039	832,673
Fayette	19,564,591	20,820,042	10,095,831	15,672,679	22,191,047
Greene	4,388,330	4,607,642	3,474,274	3,939,164	5,202,159
Huntingdon	516,427	482,593	395,075	467,100	503,031
Indiana	6,542,085	6,667,054	5,676,797	5,827,092	7,006,492
Jefferson	2,107,742	2,192,193	1,864,200	1,743,989	2,108,206
Lawrence	262,721	265,288	202,610	[3] 281,878	282,137
Lycoming	69,665	70,835	61,866	55,601	72,056
Mercer	428,955	318,813	111,760	217,521	326,951
Somerset	5,177,389	5,239,328	3,895,244	4,400,865	4,960,323
Tioga	154,946	170,318	189,359	246,940	270,515
Washington	18,637,692	18,895,224	12,595,645	15,484,985	19,395,154
Westmoreland	10,752,379	10,674,423	6,169,524	7,329,434	8,985,347
Fulton, McKean and Venango	[2] 213,782	[2] 185,882	[3] 170,461	[4] 51,794	[5] 250,194
Total	109,887,470	111,002,289	77,704,537	92,584,113	116,602,999

[1] Includes Bradford, Cameron, Forest, Fulton and Warren Counties.

[2] Includes Bradford County.

[3] Includes Crawford County.

[4] Venango County only.

[5] Includes Bradford, Cameron, Crawford and Forest Counties.

COKE AND ITS BYPRODUCTS

The development of the coke industry has been closely associated with the production of iron which supplied the principal market. In this field coke replaced anthracite and bituminous coal, which had earlier replaced charcoal. Production of coke in Pennsylvania was first referred to in 1818. It is doubtful that the output amounted to a substantial figure until some forty years later. Coke was first produced by the controlled combustion of coal piled in heaps. The brick oven did not appear until a later date. The beehive oven became firmly established as the most satisfactory method then available for coke production and the suitability of this coke for blast-furnace fuel led to a steady expansion in use. The superior coking quality of the coal obtained from the Pittsburgh bed resulted in the development of the industry in the Connellsville district, which became world famed for this product.

The installation of byproduct ovens, which has altered the whole industry, permits the recovery of valuable byproducts lost in the beehive process. The first byproduct oven installed in Pennsylvania was erected in Johnstown and put in use in 1895. This was the second installation in the United States. Since this year there has been a steady increase in the productive capacity of byproduct ovens so that byproduct coke attained a greater tonnage than beehive in 1921. With the exception of a few years this position has been maintained since. The dislocation of normal channels of trade in 1914 attracted attention to the dependence of this country upon foreign imports of synthetic chemical preparations, most of which were byproducts of the coke industry. The impetus supplied by this war-time condition led to the recognition of the importance of coal tar derivatives for many dyes, drugs, explosives and similar products, therefore American interest in these materials was accelerated to an exceptional degree. This condition has been repeated in the present war due to a record steel production made possible by adequate coke supplies. These supplies have been obtained in part by the rehabilitation of all beehive ovens possible. Beehive coke production in Pennsylvania increased over 1,000 percent from 1938 to 1941. A decrease when the peak of wartime demand is passed may be expected.

Coke-Oven Gas

Gas is now the most valuable coke-oven byproduct. In addition to supplying the fuel needs of the ovens a surplus is sold for industrial purposes and for distribution through city mains. The revenue obtained from the sale of excess gas commonly exceeds fifty percent of the total derived from all products.

Beehive Coke Oven
by Christian J. Walter

Tar

Coal tar is the basic material for hundreds of compounds. The crude tar must be processed. Plants not properly equipped sell their output to refineries. Crude tar is used as a fuel, particularly in heating open-hearths in the steel industry. This wasteful use is declining as the recovery of valuable constituents is proving to be more profitable.

Ammonia

The bulk of ammonia recovered from byproduct ovens goes into ammonium sulphate. As a matter of convenience all production is reported as though it had been converted into this compound. It is used extensively in the manufacture of nitric acid, explosives and as fertilizer.

Light Oil

Light oil contains some of the most useful derivatives of coal, particularly benzol and toluol. Phenol, aniline, picric acid, TNT, and hundreds of other less well known compounds valuable as dyes, drugs, and chemical reagents are derived from these compounds. Naphthalene, an important derivative from tar and light oil, is used as a moth repellent and in the manufacture of resins, explosives, and other materials.

Byproduct output is controlled by activity in the demand for coke, the primary product, which in turn is dominated by the demand for steel. The tonnage of byproducts therefore tends to exhibit wide variations corresponding to trends in the steel industry.

TABLE 7. COKE PRODUCED IN BYPRODUCT AND BEEHIVE COKE OVENS IN PENNSYLVANIA

Year	*Byproduct*		*Beehive*		*Total*		*Percentage of United States Total*[1]
	Net tons	*Value*	*Net tons*	*Value*	*Net tons*	*Value*	
1880	......	......	2,821,384	$5,255,042	2,821,384	$5,255,042	84.3
1881	......	......	3,437,708	5,898,579	3,437,708	5,898,579	83,5
1882	......	......	3,945,034	6,133,698	3,945,034	6,133,698	82.4
1883	......	......	4,438,464	5,410,387	4,438,464	5,410,387	81.2
1884	......	......	3,822,128	4,783,230	3,822,128	4,783,230	79.6
1885	......	......	3,991,805	4,981,656	3,991,805	4,981,656	78.3
1886	......	......	5,406,597	7,664,023	5,406,597	7,664,023	79.1
1887	......	......	5,832,849	10,746,352	5,832,849	10,746,352	76.7
1888	......	......	6,545,779	8,230,759	6,545,779	8,230,759	76.6
1889	......	......	7,659,055	10,743,492	7,659,055	10,743,492	74.8
1890	......	......	8,560,245	16,333,674	8,560,245	16,333,674	74.5
1891	......	......	6,954,846	12,679,826	6,954,846	12,679,826	67.2
1892	......	......	8,327,612	15,015,336	8,327,612	15,015,336	69.4
1893	......	......	6,229,051	9,468,036	6,229,051	9,468,036	65.7
1894	......	......	6,063,777	6,585,489	6,063,777	6,585,489	66.1
1895	......	......	9,404,215	11,908,162	9,404,215	11,908,162	70.7
1896	......	......	7,356,502	13,182,859	7,356,502	13,182,859	62.5
1897	......	......	8,966,924	13,727,966	8,966,924	13,727,966	67.5
1898	......	......	10,715,302	16,078,505	10,715,302	16,078,505	66.7
1899	......	......	13,577,870	22,881,910	13,577,870	22,881,910	69.1
1900	......	......	13,357,295	29,692,258	13,357,295	29,692,258	65.1
1901	......	......	14,355,917	27,066,361	14,355,917	27,066,361	66.0
1902	502,743	$1,477,774	16,497,910	38,451,722	17,000,653	39,929,496	66.9
1903	573,865	1,712,994	15,650,932	38,969,101	16,224,797	40,682,095	64.2
1904	813,768	1,906,309	14,861,064	25,027,462	15,674,832	26,933,771	66.4
1905	1,374,815	3,903,634	20,573,736	42,253,178	21,948,551	46,156,812	68.1
1906	......	......	23,060,511	54,184,531	23,060,511	54,184,531	63.4
1907	2,165,066	8,311,285	26,513,214	67,638,024	28,678,280	75,949,309	70.3
1908	1,286,371	4,168,935	15,511,634	32,569,621	16,798,005	36,738,556	64.5
1909	1,849,391	......	23,056,134	50,377,035	24,905,525	50,377,035	63.3
1910	2,052,973	5,881,640	24,262,634	49,372,959	26,315,607	55,254,599	63.2
1911	1,493,509	......	20,430,426	......	21,923,935	43,053,367	61.8
1912	1,974,619	6,020,383	25,464,074	50,315,872	27,438,693	56,336,255	62.4
1913	2,628,680	8,238,924	26,124,764	59,690,940	28,753,444	67,929,864	62.1
1914	2,184,336	6,569,976	18,074,057	35,877,910	20,258,393	42,447,886	58.6
1915	3,092,295	9,363,197	22,530,567	43,303,821	25,622,862	52,667,018	61.6
1916	4,120,257	14,202,090	27,159,438	70,508,215	31,279,695	84,710,305	57.4
1917	4,095,605	24,435,135	23,816,420	111,262,905	27,912,025	135,698,040	50.2
1918	4,586,981	29,618,136	22,136,664	130,739,138	26,723,645	160,357,274	47.3
1919	5,866,841	33,041,083	14,634,990	69,861,837	20,501,831	102,902,920	46.4
1920	7,730,256	77,843,678	15,908,483	139,822,353	23,638,739	217,666,031	46.0
1921	5,303,371	21,740,543	4,466,105	22,371,288	9,769,476	44,111,831	38.6
1922	7,151,912	36,702,974	6,839,980	38,091,586	13,991,892	74,794,560	37.7
1923	9,185,747	43,520,249	16,438,539	94,923,942	25,624,286	138,444,191	45.0
1924	8,426,155	34,674,512	8,501,282	37,893,584	16,927,437	72,568,096	38.2
1925	9,853,262	34,518,863	9,574,341	41,875,615	19,427,603	76,394,478	37.9
1926	11,200,624	48,722,935	10,722,352	47,595,184	21,922,976	96,318,119	38.6
1927	11,061,084	44,601,757	5,716,207	22,568,318	16,777,291	67,170,075	32.8
1928	13,475,349	51,132,406	3,442,006	11,515,366	16,917,355	62,647,772	32.0
1929	14,489,283	55,088,803	5,367,685	17,824,426	19,856,968	72,913,229	33.2
1930	12,529,255	47,691,068	2,011,324	6,407,168	14,540,579	54,098,236	30.3
1931	7,524,722	30,039,070	855,527	2,419,114	8,380,249	32,458,184	25.0
1932	4,037,810	16,021,240	506,377	1,238,846	4,544,187	17,260,086	20.9
1933	6,170,240	24,045,292	670,179	1,685,947	6,840,419	25,731,239	24.8
1934	6,834,362	27,603,302	720,593	2,554,813	7,554,955	30,158,115	23.7
1935	8,078,175	32,105,648	564,052	2,101,002	8,642,227	34,206,650	24.6
1936	12,570,816	49,644,435	1,213,294	4,565,024	13,784,110	54,209,459	29.8
1937	13,701,262	55,142,252	2,559,048	10,699,200	16,260,310	65,841,452	31.0
1938	7,119,328	30,070,706	482,105	1,945,790	7,601,433	32,016,496	23.4
1939	10,994,254	44,214,472	1,125,971	4,801,086	12,120,225	49,015,558	27.3
1940	14,861,657	58,619,692	2,550,367	10,979,384	17,412,024	69,599,076	30.5

NOTE: Byproduct coke first made in Penna. in 1895. [1] Calculated by weight. SOURCE: *Mineral Resources of the U. S.* and *Minerals Yearbook*.

TABLE 8. COKE-OVEN GAS PRODUCED IN PENNSYLVANIA

Year	*Production (M cubic feet)*	*Used in heating ovens (M cubic feet)*	*Surplus sold or used*	
			Quantity (M cubic feet)	*Value*
1920	122,840,496	60,967,169	60,541,987	$6,282,329
1921	83,790,113	37,747,014	43,797,582	4,604,939
1922	105,567,898	47,390,995	57,280,890	6,265,001
1923	146,208,327	65,654,370	78,213,805	8,766,670
1924	138,625,989	55,643,934	81,435,748	8,793,586
1925	168,037,483	68,945,204	96,694,286	10,702,786
1926	193,828,548	82,513,506	108,486,844	11,560,528
1927	190,467,082	79,369,435	107,851,071	11,317,598
1928	230,927,005	95,191,806	127,030,703	12,972,877
1929	240,552,305	97,282,507	136,629,648	15,172,152
1930	211,603,231	84,449,404	118,909,355	14,133,408
1931	127,032,697	53,986,959	71,561,132	9,910,220
1932	69,703,935	28,928,862	40,245,502	6,979,909
1933	103,011,775	40,825,405	58,234,395	8,286,026
1934	113,654,274	47,340,167	64,948,812	8,962,695
1935	136,883,771	55,373,905	80,626,086	10,194,485
1936	208,571,379	82,681,832	122,095,021	13,832,798
1937	221,351,285	86,843,114	131,803,433	14,989,921
1938	118,591,838	47,981,230	70,155,151	9,026,204
1939	181,809,635	71,978,547	109,162,063	12,919,071
1940	242,692,013	97,839,787	143,367,654	16,214,547
1941	253,153,398	103,884,214	148,329,055	17,264,504

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 9. COKE-OVEN TAR PRODUCED AND SOLD IN PENNSYLVANIA

Year	*Amount Produced (Gallons)*	*Amount Sold*	
		Gallons	*Value*
1920	106,862,576	17,693,346	$726,441
1921	80,595,363	28,270,055	1,100,130
1922	89,374,955	17,888,263	692,933
1923	121,522,057	19,569,138	807,637
1924	124,442,164	26,490,174	1,016,401
1925	137,170,914	32,232,601	1,301,373
1926	159,618,134	37,874,279	1,586,980
1927	162,644,461	53,364,509	2,469,719
1928	214,126,173	65,782,499	3,060,850
1929	231,057,712	51,143,455	2,279,842
1930	197,576,541	51,376,351	2,298,148
1931	121,678,511	32,561,203	1,359,530
1932	69,394,326	24,611,892	903,520
1933	96,238,465	28,010,859	952,743
1934	107,765,616	30,945,201	1,169,633
1935	129,574,979	42,434,750	1,453,845
1936	189,066,960	56,675,849	1,938,265
1937	200,816,522	54,795,232	2,119,076
1938	113,151,706	29,288,027	1,300,083
1939	169,081,691	31,733,459	1,391,046
1940	221,897,903	32,260,815	1,483,871
1941	229,170,465	30,255,291	1,384,711

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 10. AMMONIA PRODUCED AT COKE-OVEN PLANTS IN PENNSYLVANIA

Year	*Sulphate Equivalent (Pounds)*	*Year*	*Sulphate Equivalent (Pounds)*
1920	242,308,762	1931	290,131,735
		1932	149,115,173
1921	186,256,676	1933	208,416,276
1922	237,359,865	1934	236,954,502
1923	297,442,688	1935	296,943,586
1924	294,325,226		
1925	333,385,427	1936	432,614,924
		1937	459,539,764
1926	379,928,229	1938	253,618,391
1927	392,591,663	1939	378,404,833
1928	480,957,647	1940	507,601,971
1929	497,135,077		
1930	471,101,872	1941	522,401,649

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 11. CRUDE LIGHT OIL PRODUCED AT COKE-OVEN PLANTS IN PENNSYLVANIA

Year	*Gallons*	*Year*	*Gallons*
1921	23,868,704	1931	35,468,701
1922	29,497,158	1932	17,807,670
1923	38,397,061	1933	27,173,676
1924	37,705,872	1934	30,838,284
1925	44,026,763	1935	38,370,266
1926	50,026,664	1936	56,681,746
1927	50,520,585	1937	61,353,947
1928	64,095,947	1938	33,350,074
1929	65,700,270	1939	51,853,145
1930	60,390,612	1940	67,896,978

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

MANUFACTURED GAS

Gas manufactured from coal, with additions of some excess coke-oven gas, is distributed by the public utilities essentially for industrial use and home heating and cooking. Sales of such gas in recent years are shown in the following table:

TABLE 12. MANUFACTURED GAS SOLD BY PUBLIC UTILITIES IN PENNSYLVANIA[1]

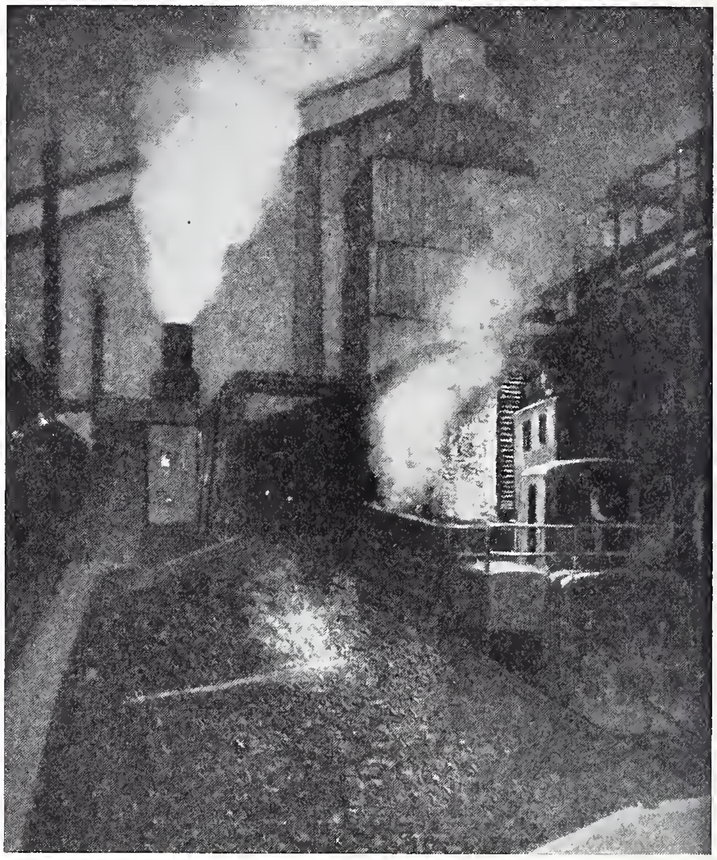
Year	*M Cubic Feet*	*Year*	*M Cubic Feet*
1921	23,661,560	1932	33,828,823
1922	24,233,794	1933	33,940,342
1923	26,624,104	1934	34,736,674
1924	26,603,396	1935	34,298,965
1925	27,102,134	1936	35,081,964
1926	30,501,187	1937	34,882,617
1927	30,484,736	1938	38,440,549
1928	31,633,645	1939	34,727,935
1929	33,213,658	1940	33,371,232
1930	34,846,307	1941	34,702,059
1931	35,546,765	1942	38,075,201

[1] Includes coke oven gas produced or purchased for resale.

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

PETROLEUM

The history of the petroleum industry records that the first intentional drilling for the commercial production of oil occurred in Pennsylvania in 1859. Though Pennsylvania was the principal oil producing State of the United States for only a short period, it has always been a pioneering State. It is in Pennsylvania that the application of secondary methods of production found their first field of application and, presently, it is in the same State that a serious effort at oil mining is being carried out, thereby ascertaining the possibilities of producing a third crop of oil.



By-products Coking Plant
by A. H. Gorson

Oil production in Pennsylvania reached its peak in the year 1891, mostly due to the full development of the Bradford field's primary production as well as a number of large flowing wells in the southwestern part of the State. From 1891 to 1922, the oil production in Pennsylvania has been constantly declining, as few new pools were discovered and the pressure in the known pools was gradually exhausted. The application of the principles of oil field rejuvenation did not start on an appreciable scale until the legalization of artificial water drive in 1921 by an act of the State Legislature, which permitted the injection of water under pressure into known oil sands. The effects of this legislation were not apparent until the late 20's when the State's oil production again reached the 10 million barrel mark. During the 30's, oil production climbed at an accelerated rate, mostly due to water-flooding in the Bradford field becoming general practice, and passed the 16 million barrel mark in 1937. As the total Pennsylvania production in that year reached a new high of over 19 million barrels, it is seen that the contribution of secondary recovery methods other than water-flooding, as well as of primary production (mostly due to the newly discovered Music Mountain field), amounted to only 15 percent of the total.

TABLE 13. PETROLEUM PRODUCED OR MARKETED IN PENNSYLVANIA

Year	Barrels[1]	Value[1]
1859	2,000	$3,200
1860	500,000	......
1861	2,113,609	......
1862	3,056,690	......
1863	2,611,309	......
1864	2,116,109	......
1865	2,497,700	......
1866	3,597,700	......
1867	3,347,300	......
1868	3,646,117	......
1869	4,215,000	......
1870	5,260,745	......
1871	5,205,234	......
1872	6,293,194	......
1873	9,893,786	......
1874	10,926,945	......
1875	8,787,514	......
1876	8,968,906	......
1877	13,135,475	......
1878	15,163,462	......
1879	19,685,176	......
1880	26,027,631	......
1881	27,376,509	......
1882	30,053,500	......
1883	23,128,389	......
1884	23,772,209	......
1885	20,776,041	......
1886	25,798,000	......
1887	22,356,193	......
1888	16,488,668	......
1889	21,487,435	23,475,163
1890	28,458,208	[2] 22,687,495
1891	31,424,206	21,240,735
1892	27,149,034	15,302,968
1893	19,283,122	12,563,893
1894	18,077,559	15,342,966
1895	18,231,442	24,900,630
1896	19,379,201	22,982,402
1897	17,982,911	14,295,825
1898	14,743,214	13,608,002
1899	13,053,603	17,053,410
1900	13,258,202	18,088,016
1901	12,625,378	$15,430,609
1902	12,063,880	15,266,093
1903	11,355,156	18,170,881
1904	11,125,762	18,222,242
1905	10,437,195	14,653,278
1906	10,256,893	16,596,943
1907	9,999,306	17,579,706
1908	9,424,325	16,881,194
1909	9,299,403	15,424,554
1910	8,794,662	11,908,914
1911	8,248,158	10,894,074
1912	7,837,948	12,886,752
1913	7,917,302	19,690,502
1914	8,170,335	15,573,822
1915	7,838,705	12,431,353
1916	7,592,394	19,149,855
1917	7,733,200	25,154,290
1918	7,407,812	29,606,079
1919	8,137,000	33,688,000
1920	7,438,000	44,464,000
1921	7,418,000	24,746,000
1922	7,425,000	23,834,000
1923	7,609,000	25,320,000
1924	7,486,000	27,025,000
1925	8,097,000	29,310,000
1926	8,961,000	31,930,000
1927	9,526,000	29,150,000
1928	9,956,000	32,550,000
1929	11,820,000	44,800,000
1930	12,803,000	33,410,000
1931	11,892,000	23,550,000
1932	12,412,000	23,400,000
1933	12,624,000	23,590,000
1934	14,478,000	35,200,000
1935	15,810,000	33,840,000
1936	17,070,000	41,450,000
1937	19,189,000	49,300,000
1938	17,426,000	32,760,000
1939	17,382,000	36,200,000
1940	17,353,000	39,700,000
1941	16,750,000	43,050,000

[1] New York included with Pennsylvania, 1859 to 1890 inclusive.

[2] Calculated at an average price of 86.75 cents per barrel.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

Total crude petroleum production statistics for Pennsylvania are given in the foregoing table for each year from 1859 to date. A second table, from a different source, shows petroleum production in more recent years by counties. It should be observed that the county figures are obtained directly from pipeline companies and that precautions are taken to eliminate duplication of the same oil reported by two or more companies.

NATURAL GAS

The State of Pennsylvania has pioneered in the development of the natural gas industry both in production and in pipe-line transmission. Until the opening up of the great oil and gas fields in the Gulf Coast and Mid-continent States and the completion of pipe lines for delivering that gas to market areas, the Appalachian region, in which Pennsylvania is a leading producer, was the principal producing area in the country.

The figures in the table on page 34 show that the production of natural gas in Pennsylvania has been declining slowly since 1906. The markedly lowered production during the years 1931-1934 was a temporary phase occasioned by the lack of market demands during the worst of the depression years. The subsequent recovery in production has been due to an increased demand for gas and the drilling of new wells. Deeper wells were put down in the Oriskany sand and numerous shallow wells were developed.

A striking feature of the natural gas industry in Pennsylvania is the large number of wells in active production. In 1941 there were 18,300 producing wells in this State. This may be compared with gas production in California in the same year, when four times the amount of natural gas produced in Pennsylvania was obtained from only 110 wells.

Pennsylvania holds seventh place among producing States in this country but ranks fifth from the standpoint of consumption. Natural gas is a premium fuel for many industrial uses but it is obvious that if use of this gas is to be continued at the present rate in-

TABLE 14. CRUDE PETROLEUM PRODUCED IN PENNSYLVANIA, BY COUNTIES
(Barrels)

County	*1921*	*1922*	*1923*	*1924*	*1925*
Allegheny	598,480	574,552	561,398	467,265	453,648
Armstrong	24,807	24,788	24,266	21,350	20,093
Beaver	125,795	117,913	109,140	91,973	83,908
Butler	874,878	825,366	781,402	735,900	846,151
Clarion	230,044	212,176	210,914	203,685	208,807
Crawford	48,298	48,406	59,024	56,613	57,637
Elk	116,432	109,244	101,642	100,701	93,546
Forest	96,033	87,226	82,707	87,369	131,162
Greene	413,163	317,343	274,229	249,871	302,938
Jefferson	13,210	10,036	9,237	8,436	8,527
Lawrence	31,736	31,825	28,654	24,215	22,537
McKean	2,311,662	2,466,723	2,490,696	2,374,775	2,575,089
Mercer	14,795	12,954	13,643	13,503	13,804
Potter	13,612	13,375	12,135	10,011	11,686
Tioga	10,095	8,779	7,712	6,836	5,916
Venango	1,454,528	1,360,093	1,304,206	1,236,568	1,184,221
Warren	342,640	516,781	522,107	326,852	294,597
Washington	531,117	499,893	474,765	478,483	455,554
Westmoreland	150	233	215	257	186
TOTAL	7,251,475	7,237,706	7,068,092	6,494,663	6,770,007

County	*1926*	*1927*	*1928*	*1929*	*1930*
Allegheny	422,797	406,771	375,062	349,497	326,050
Armstrong	19,718	19,420	18,319	19,564	34,435
Beaver	84,296	81,198	77,153	71,744	66,112
Butler	700,241	677,004	646,942	679,752	606.211
Clarion	209,965	190,365	189,740	195,665	178,839
Crawford	64,523	75,235	79,482	99,614	104,759
Elk	88,419	86,213	85,643	92,058	86,736
Fayette	......	......	......	1,721	......
Forest	137,078	127,814	160,577	102,017	103,271
Greene	439,576	370,612	228,199	276,263	244,495
Jefferson	21,167	7,687	6,744	5,966	6,187
Lawrence	31,192	27,319	24,921	21,435	31,044
McKean	4,428,540	5,884,787	5,901,394	7,734,945	8,797,217
Mercer	14,401	14,031	15.489	22,022	16,070
Potter	7,395	6,860	8,849	3,122	5,863
Tioga	2,441	......	......	......	......
Venango	1,179,339	1,214,568	1,147,047	1,291,487	1,132,969
Warren	313,808	343,315	299,282	315,322	317,025
Washington	449,493	455,807	500,019	490,142	476,964
TOTAL	8,614,389	9,989,006	9,764,862	11,772,336	12,534,247

creasing amounts of gas will have to be brought into the State.

NATURAL GAS GASOLINE

The casing head gasoline industry is reported to have originated in Pennsylvania in or about the year 1904. In the Fall of that year gasoline was recovered from the gas of wells near Titusville. From this pioneer operation alone the output the first year aggregated 4,000 gallons and the price received for the gasoline was 10 cents a gallon. At about the same time other plants were installed at Tidioute and Warren, but it was not until 1910 that the new industry assumed real importance. In the following year the United States Geological Survey began to compile statistics of the annual output of gasoline derived from natural gas.

Table 14. CRUDE PETROLEUM PRODUCED IN PENNSYLVANIA, BY COUNTIES—Continued
(Barrels)

County	*1931*	*1932*	*1933*	*1934*	*1935*
Allegheny	293,685	250,042	254,527	275,842	267,955
Armstrong	24,788	23,262	22,576	20,957	22,211
Beaver	58,606	47,999	43,006	43,499	42,374
Butler	564,330	526,848	482,912	466,973	467,130
Clarion	169,349	161,592	144,053	141,515	140,002
Crawford	105,237	97,589	100,483	92,904	93,388
Elk	84,136	81,147	74,118	74,923	71,548
Forest	93,290	94,338	93,239	90,296	94,448
Greene	207,349	171,948	169,324	190,969	192,730
Jefferson	6,344	5,462	4,832	6,556	7,063
Lawrence	23,029	20,580	18,092	17,668	14,915
McKean	8,385,975	8,991,026	9,466,346	11,041,106	12,813,267
Mercer	14,437	13,745	13,596	12,383	12,484
Potter	6,206	7,500	8,345	9,205	11,031
Venango	1,083,989	1,027,450	946,342	902,195	917,189
Warren	303,078	307,616	300,687	421,255	290,826
Washington	420,333	380,249	416,709	507,681	479,888
Westmoreland[1]	374	172	302	202	165
Total	11,844,535	12,208,565	12,559,489	14,316,129	15,938,614

County	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*
Allegheny	273,213	271,392	254,614	269,240	247,572	224,119
Armstrong	21,855	22,157	21,270	22,137	22,715	21,543
Beaver	36,699	38,214	37,695	35,896	31,597	30,415
Butler	457,375	450,787	446,834	431,019	408,122	368,176
Clarion	141,123	139,089	127,971	121,401	112,021	102,618
Crawford	87,353	95,194	90,290	86,774	84,199	80,192
Elk	71,732	72,363	69,330	72,544	76,578	88,912
Forest	95,263	97,340	95,377	91,396	81,209	73,432
Greene	209,957	265,017	242,266	213,212	180,879	163,871
Jefferson	6,787	7,253	6,947	5,672	5,500	5,829
Lawrence	13,216	12,342	12,090	13,604	11,859	7,511
McKean	13,871,170	16,454,744	14,146,004	14,060,287	14,311,090	13,886,828
Mercer	10,595	11,018	10,129	9,885	8,421	8,891
Potter	11,031	10,124	9,963	10,286	10,238	32,978
Venango	908,313	965,446	1,039,506	977,751	945,951	920,594
Warren	465,196	615,732	582,552	521,790	504,415	536,940
Washington	455,652	462,580	432,978	412,946	392,219	366,459
Westmoreland[1]	104	78	87	.....	41	......
Total	17,136,634	19,990,870	17,625,903	17,355,840	17,434,626	16,919,308

[1] Pumped from gas wells.

Source: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

TABLE 15. NATURAL GAS PRODUCED AND CONSUMED IN PENNSYLVANIA

	Production		*Consumption*	
Year	*Quantity (M Cubic Feet)*	*Value at Points of Consumption*	*Quantity (M Cubic Feet)*	*Value, Incl. Receipts from Other States*
1882	......	$75,000	......	$75,000
1883	......	200,000	......	200,000
1884	......	1,100,000	......	1,100,000
1885	......	4,500,000	......	4,500,000
1886	......	9,000,000	......	9,000,000
1887	......	13,749,500	......	13,749,500
1888	......	19,282,375	......	19,282,375
1889	......	11,593,989	......	11,593,989
1890	......	9,551,025	......	9,551,025
1891	......	7,834,016	......	7,834,016
1892	......	7,376,281	......	7,376,281
1893	......	6,488,000	......	6,488,000
1894	......	6,279,000	......	6,279,000
1895	......	5,852,000	......	5,852,000
1896	......	5,528,610	......	4,616,610
1897	......	6,242,543	......	6,242,543
1898	......	6,806,742	......	6,806,742
1899	......	8,337,210	......	7,926,970
1900	......	10,215,412	......	9,812,615
1901	......	12,688,161	......	11,785,996
1902	......	14,352,183	......	13,942,783
1903	......	16,182,834	......	16,060,196
1904	......	18,139,914	......	17,205,804
1905	......	19,197,336	......	19,237,218
1906	138,161,385	18,558,245	162,095,173	21,085,077
1907	135,516,015	18,844,156	164,541,179	22,917,547
1908	130,476,237	19,104,944	147,790,097	20,678,161
1909	127,697,104	20,475,207	163,656,145	21,639,102
1910	126,866,729	21,057,211	168,875,559	23,934,691
1911	108,869,296	18,520,796	159,104,376	23,940,001
1912	112,149,855	18,539,672	173,656,003	26,486,302
1913	118,860,269	21,695,845	177,463,230	28,709,565
1914	110,745,374	20,839,869	164,834,542	28,439,324
1915	113,691,690	21,139,605	176,367,235	30,087,667
1916	129,925,150	24,344,324	201,460,893	35,015,695
1917	133,397,206	28,716,492	202,259,498	40,773,689
1918	123,813,358	38,608,883	177,139,804	44,777,220
1919	113,489,000	32,520,000	146,553,000	41,269,000
1920	125,787,000	40,726,000	161,397,000	51,863,000
1921	86,144,000	32,815,000	100,615,000	38,246,000
1922	101,276,000	39,835,000	130,733,000	50,657,000
1923	112,562,000	45,873,000	138,478,000	54,742,000
1924	105,863,000	45,546,000	123,932,000	52,005,000
1925	101,632,000	47,098,000	119,475,000	53,946,000
1926	107,089,000	50,040,000	125,836,000	56,724,000
1927	105,709,500	49,135,000	121,982,000	54,473,000
1928	99,466,000	48,432,000	116,150,000	54,388,000
1929	101,951,000	48,821,000	122,876,000	56,900,000
1930	88,706,000	44,521,000	108,218,000	51,760,000
1931	74,797,000	37,827,000	92,629,000	44,359,000
1932	61,611,000	32,080,000	76,935,000	37,951,000
1933	63,579,000	31,979,000	73,627,000	34,182,000
1934	86,238,000	37,524,000	87,474,000	37,651,000
1935	94,464,000	39,434,000	91,601,000	38,531,000
1936	110,362,000	42,874,000	110,195,000	44,760,000
1937	115,928,000	41,842,000	119,501,000	47,537,000
1938	76,547,000	29,544,000	96,285,000	40,959,000
1939	93,882,000	35,268,000	109,746,000	43,585,000
1940	90,725,000	41,733,000	121,230,000	50,456,000

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 16. NATURAL GAS GASOLINE PRODUCED IN PENNSYLVANIA

Year	*Quantity (gallons)*	*Value*
1911	1,467,043	$109,649
1912	2,041,109	217,016
1913	3,680,096	405,186
1914	4,611,738	359,402
1915	5,898,597	569,873
1916	9,714,926	1,726,173
1917	13,826,250	2,778,098
1918	15,775,058	3,249,233
1919	20,283,336	4,407,318
1920	21,151,135	4,382,380
1921	19,856,373	3,354,233
1922	18,518,131	3,144,545
1923	19,132,000	2,560,000
1924	19,254,000	2,266,000
1925	18,850,000	2,185,000
1926	20,343,000	2,454,000
1927	16,744,000	1,648,000
1928	16,571,000	1,570,000
1929	18,411,000	1,676,000
1930	16,713,000	1,229,000
1931	14,339,000	706,000
1932	11,685,000	535,000
1933	11,686,000	568,000
1934	10,781,000	467,000
1935	12,623,000	628,000
1936	14,267,000	722,000
1937	13,940,000	701,000
1938	10,734,000	526,000
1939	11,756,000	499,000
1940	15,371,000	594,000
1941	15,440,000	705,000

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

PORTLAND CEMENT

The production of portland cement has been associated with the industrial development of Pennsylvania since 1878 when this material was made for the first time in America, in the Lehigh Valley. Expansion in this industry was rapid in this district because of its remarkable reserves of suitable raw material and its proximity to large markets. The State acquired first rank as a producer of portland cement in the early years of the industry, a position consistently maintained since. The concentration of productive capacity in eastern Pennsylvania is unequaled elsewhere. Most of the technique relating to the burning of the clinker, its grinding, and the use of proper retarders to regulate the time of set were worked out here.

The suitability of the Lehigh Valley rock for the manufacture of cement was so marked that for a considerable period operations were restricted to its use. Later technical investigations demonstrated that many lime-bearing materials could be used. Limestone, oyster shells, marl, and blast-furnace slag are now used with the addition of other materials containing the proper amounts of alumina and silica. The geographical distribution of portland cement plants has been extended greatly. In 1941, cement was produced in 35 States.

Of the 155 mills active in the United States, 25 were in Pennsylvania and they produced 19.5 percent of all the cement manufactured. The percentage of the country's total contributed by Pennsylvania has displayed an almost constant decline since 1910 due largely to increased production in other areas. The State industry enjoyed its peak production from 1923 to 1929 when construction and road-building were both active. Production is still far below capacity and future improvement is dependent upon expansion in construction.

Perhaps no commodity is sold at such a low price per ton as portland cement in relation to the capital invested and the amount of highly skilled technical effort applied to its manufacture. Its availability at the prices commonly current is a striking example of economic production by the application of modern technology. In the past few years there has been a marked trend toward the making of many special cements in place of one standard material.

Cements having high early strength have done much to diminish the delays of construction; others have been developed to set with a minimum of heat evolution, some to possess great plasticity for masonry use, and others to resist various corrosive reagents. This has been reflected in production methods and in raw materials used. Iron oxide, to mention one specific case, is now an important raw material in the manufacture of certain cements and is used in Pennsylvania by the thousands of tons.

LIME

The production of lime in Pennsylvania is an old industry. Lime mortar was employed in the masonry of the earliest stone and brick buildings. Limestones of many types varying from high-calcium to almost pure dolomite are widely distributed. Some of these are also employed in the manufacture of portland cement and these two industries are closely associated in a number of districts. Of the 309 lime plants reporting production in 1941, 89 were in Pennsylvania. This number is greater than in any other State. In

TABLE 17. PORTLAND CEMENT PRODUCED AND SHIPPED IN PENNSYLVANIA

Year	*Production (barrels)*	*Value*	*Shipments (barrels)*	*Value*
1891	268,500	$532,850	......	......
1892	300,840	597,100	......	......
1893	285,317	521,411	......	......
1894	437,106	718,009	......	......
1895	504,276	756,414	......	......
1896	825,054	1,224,294	......	......
1897	1,579,724	2,369,586	......	......
1898	2,095,141	3,142,711	......	......
1899	3,217,965	4,290,620	......	......
1900	4,984,417	4,984,417	......	......
1901	7,091,500	6,382,350	......	......
1902	8,770,454	10,130,432	......	......
1903	9,754,313	11,205,892	......	......
1904	11,496,099	8,969,206	......	......
1905	13,813,487	11,195,940	......	......
1906	18,645,015	18,598,439	......	......
1907	20,393,965	19,698,006	......	......
1908	18,254,806	13,899,807	......	......
1909	22,869,614	15,969,621	......	......
1910	26,675,978	19,551,268	......	......
1911	26,864,679	19,258,253	......	......
1912	26,441,338	......	27,539,076	$18,918,165
1913	28,701,845	28,845,355	28,060,495	24,268,800
1914	26,570,151	24,630,529	25,985,106	20,944,787
1915	28,648,941	......	28,188,450	20,252,961
1916	27,323,147	......	28,748,546	27,915,298
1917	27,752,838	......	27,709,442	34,512,388
1918	22,628,901	......	22,238,689	33,600,956
1919	25,325,173	......	26,250,077	43,126,528
1920	28,269,314	......	27,662,116	52,632,082
1921	27,628,598	......	26,622,367	46,881,625
1922	33,276,093	......	34,023,695	55,528,002
1923	38,157,482	......	38,610,852	69,792,343
1924	40,849,602	......	40,208,860	69,693,517
1925	42,346,830	......	41,899,787	72,870,981
1926	42,865,694	......	41,395,604	70,437,218
1927	43,732,278	......	42,909,513	66,711,069
1928	41,522,401	......	41,161,019	62,572,588
1929	39,354,470	......	39,309,662	55,600,953
1930	37,843,662	......	37,968,647	52,712,176
1931	28,510,231	......	28,412,975	30,952,302
1932	15,798,724	......	16,937,209	16,670,336
1933	12,294,374	......	12,486,585	15,696,852
1934	15,323,116	......	15,435,648	23,138,676
1935	15,502,086	......	15,034,441	21,917,366
1936	22,870,689	......	22,527,491	33,235,017
1937	23,064,465	......	22,952,603	31,917,831
1938	20,868,384	......	21,082,966	28,242,913
1939	25,105,902	......	24,870,343	34,332,649
1940	26,853,002	......	27,499,786	38,350,998
1941	32,199,184	......	32,868,220	45,383,766

addition, several small plants, intermittently operated, perform a useful purpose in supplying lime for local agriculture. Many farmers burn their own limestone with local coal or wood and so make a satisfactory lime for the soil.

In the early days of the lime industry most of the production was used for construction. It provided the only material for mortar and plastering walls. The recognition of its value for neutralizing acid soils and as a plant food led to its extensive use in agriculture. In the construction field, lime has lost ground steadily. The use of gypsum for wall plasters has excluded lime from a large market which it previously dominated. This shrinkage in the markets for lime would have been serious if it had not been compensated for by a rapid and steady expansion in the demands for chemical lime. The growth of the chemical industry has been accompanied by a large increase in the tonnage of lime consumed in many diverse activities. Lime is the cheapest alkali available and in addition has many properties related to its calcium content. The distribution of Pennsylvania lime to the market for 1941 is shown by the following table:

TABLE 18. DISTRIBUTION OF LIME PRODUCTION IN PENNSYLVANIA IN 1941

Industry	*Tons*
Building	87,453
Agriculture	190,553
Paper mills	95,005
Tanneries	31,221
Metallurgy	304,220
Other Uses	127,235

TABLE 19. LIME BURNED AND SOLD BY PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1904	567,300	$1,537,673	1923	772,839	$6,372,732
1905	620,018	1,672,267	1924	700,380	5,634,806
1906	624,060	1,857,754	1925	794,951	6,425,675
1907	655,166	2,075,842	1926	794,196	6,303,312
1908	582,352	1,883,496	1927	813,571	6,105,241
1909	881,439	2,532,454	1928	834,050	6,119,036
1910	877,714	2,440,350	1929	782,915	5,896,752
1911	841,723	2,688,374	1930	633,520	4,661,670
1912	849,159	2,679,420	1931	497,258	3,378,088
1913	852,927	2,743,197	1932	374,244	2,327,131
1914	849,963	2,740,238	1933	430,000	2,790,000
1915	901,549	2,947,058	1934	434,519	3,165,539
1916	972,343	3,857,553	1935	531,501	3,703,339
1917	936,209	5,900,056	1936	661,464	4,644,027
1918	801,834	6,654,407	1937	692,935	5,117,733
1919	779,608	6,181,710	1938	532,066	3,784,462
1920	784,083	7,519,147	1939	691,460	4,744,197
1921	509,891	4,247,509	1940	833,038	5,622,725
1922	719,536	5,581,794	1941	1,003,039	7,263,779

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 20. HYDRATED LIME SOLD BY PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1916	126,890	$585,847	1929	259,251	$2,232,117
1917	142,254	974,936	1930	234,192	1,904,179
1918	133,583	1,126,957	1931	183,795	1,449,838
1919	166,282	1,607,090	1932	152,095	1,050,378
1920	169,639	1,884,787	1933	138,000	973,762
1921	135,917	1,311,678	1934	136,665	1,086,465
1922	172,179	1,571,709	1935	170,517	1,292,033
1923	177,836	1,740,209	1936	197,122	1,466,948
1924	189,431	1,727,749	1937	212,513	1,751,086
1925	219,737	2,020,337	1938	178,180	1,363,343
1926	237,066	2,061,741	1939	187,228	1,387,578
1927	264,491	2,147,828	1940	217,774	1,529,138
1928	273,973	2,185,386	1941	250,733	1,955,757

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

Hydrated lime is produced by a number of manufacturers. Mason's hydrate is used extensively. Curiously the limestones of Pennsylvania so far have been unable to produce a hydrate with a plasticity equal to that coming from Ohio.

CLAY PRODUCTION

Pennsylvania leads the country in the manufacture of fire-clay refractories, which are used in the steel and glass industries. The production of fire clay and, in turn, the fabrication of refractories, follows the trend of industrial activity. Since 1922 the value of fire clay and stoneware clay produced has ranged between approximately one million and two million dollars a year. In the year 1932, however, production was about one-half the normal amount. The refractory flint clays, plastic fire clays, and refractory bond clays account for the greatest volume of production.

Clay sold as kaolin probably comes largely from the deposits of residual white clays found in the south-central part of the State. These clays are used chiefly in refractories and for whitening portland cement, and, to a limited extent, as fillers and in white china bodies. Production has reached a more or less stable value of about $150,000 a year. It is believed that additional markets could be found in the fields of whiteware bodies and as paper fillers, etc., if the producers would process these clays to remove more of the fine silica associated with the clays.

Miscellaneous clays and shales are used in the pro-

TABLE 21. CLAYS SOLD OR USED BY PRODUCERS IN PENNSYLVANIA

Year	*Kaolin* [1]		*Fireclay*		*Miscellaneous*		*Stoneware*	
	Net tons	*Value*	*Net tons*	*Value*	*Net tons*	*Value*	*Net tons*	*Value*
1900	5,834	$44,507	128,666	$179,442	2,098	$12,410	1,957	$640
1901	20,047	105,891	112,227	207,305	9,433	17,892	2,796	2,343
1902	21,389	128,730	100,520	123,915	..	..	[2]	[2]
1903	23,976	145,056	138,402	201,962	5,609	6,862	2,676	888
1904	4,507	23,615	155,765	193,397	18,285	12,883	3,485	1,475
1905	7,006	39,206	194,539	250,515	12,506	16,141	4,459	4,223
1906	6,831	38,663	300,386	392,545	57,773	31,540	1,767	543
1907	4,785	23,808	296,278	433,714	13,328	14,121	4,916	4,884
1908	18,309	110,317	179,555	297,196	8,416	8,506	5,784	4,731
1909	18,113	106,228	342,496	494,235	4,509	6,337	[2]	[2]
1910	20,327	117,021	345,388	478,619	10,655	6,777	9,066	5,760
1911	23,549	135,288	281,212	411,884	6,404	3,841	3,802	2,820
1912	27,003	154,799	372,944	537,898	26,251	16,736	[2]	[2]
1913	25,069	148,347	421,751	656,825	20,333	15,914	....	.
1914	26,124	161,451	306,183	519,505	14,615	9,810	[2]	[2]
1915	20,593	128,291	377,090	567,913	33,507	27,309	[2]	[2]
1916	28,207	183,397	512,304	890,917	25,178	14,739	[2]	[2]
1917	25,014	217,008	441,344	1,118,343	34,382	21,859	[2]	[2]
1918	27,611	256,159	529,487	1,403,545	33,500	34,580	[2]	[2]
1919	21,618	232,232	367,621	1,089,910	25,858	27,324		
1920	20,164	298,213	543,610	1,946,772	29,393	69,426	9,833	17,814
1921	12,331	146,768	220,578	713,345	19,558	28,947	1,712	6,334
1922	44,289	297,197	290,701	936,134	44,401	70,016	1,868	2,906
1923	60,669	378,712	412,744	1,172,333	36,606	58,266	7,373	17,571
1924	62,596	352,507	554,257	1,513,286	41,103	64,204	3,962	12,711
1925	66,539	342,385	602,159	1,740,326	88,860	130,890	1,787	5,057
1926	72,784	346,894	717,086	2,121,474	64,332	90,407	1,630	4,599
1927	75,939	342,607	700,869	1,895,668	119,667	161,409	1,323	3,744
1928	71,552	383,675	865,024	2,100,469	[2]	[2]	[2]	[2]
1929	66,215	330,912	924,962	2,174,582	62,263	102,065	1,344	3,973
1930	78,763	251,976	633,674	1,566,730	85,334	139,861	3,782	6,619
1931	39,018	175,579	383,679	962,304	33,023	59,276	3,100	8,450
1932	13,417	54,082	166,052	460,716	12,119	20,208	16,545	16,603
1933	19,040	76,656	369,514	867,131	9,389	14,483	[2]	[2]
1934	22,219	67,779	385,471	1,002,334	26,941	41,554	15,293	15,100
1935	30,478	97,322	623,344	1,333,104	21,401	21,767	....	....
1936	42,370	138,962	733,049	1,741,633	43,211	109,228	....	....
1937	45,916	152,996	779,745	2,038,524	50,208	53,481	....	....
1938	44,312	146,289	338,864	927,370	39,196	23,136	....	....
1939	49,657	164,562	572,191	1,478,729	45,292	31,728	....	....
1940	49,541	169,981	794,702	1,984,272	54,930	35,256	....	....

NOTE: Stoneware clay included in fire clay from 1935 to 1940 inclusive.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

[1] Including some china and paper clay.

[2] Not tabulated separately for Pennsylvania.

duction of face brick, common brick, hollow construction tile, paving brick, and other structural clay products. The value of the clays is relatively low, and not at all a true indication of the value of the products made from them, inasmuch as the labor and fuel costs involved in shaping, drying, and firing such products must be included in the price of the finished ware.

Pennsylvania has a large and growing whiteware industry. Manufacturers of electrical porcelain, hotel and household china, and vitreous sanitary ware use clays shipped from North Carolina, Georgia, Florida, Kentucky, and Tennessee, since most Pennsylvania clays are not suited for this purpose.

GLASS SAND, OTHER SAND AND GRAVEL

All types of sand and gravel have been classed together as a matter of convenience in reporting total tonnage. It will be noted that the tonnage involved is large, exceeding 12 million tons in times of business activity. The value is low, consistently less than one dollar per ton. The material, with a few special exceptions, can be shipped only short distances. Consumption is, therefore, restricted to areas close to points of production.

This general table is broken down according to the use in the following pages.

TABLE 22. PRODUCTION OF GLASS SAND, OTHER SAND, AND GRAVEL IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1902	745,165	$590,733	1922	7,352,988	$7,413,686
1903	627,151	701,896	1923	9,221,292	9,944,019
1904	2,137,738	1,280,594	1924	11,315,209	10,927,752
1905	4,028,804	2,236,309	1925	12,604,065	11,438,788
1906	5,232,875	2,480,811	1926	12,873,953	11,695,218
1907	5,799,448	2,782,568	1927	13,832,181	12,040,406
1908	4,120,442	2,203,056	1928	12,955,790	11,289,826
1909	5,199,747	2,513,070	1929	12,674,320	13,658,328
1910	5,676,509	2,974,221	1930	11,012,512	11,107,825
1911	5,689,059	3,025,267	1931	8,238,926	6,977,246
1912	6,509,333	3,371,513	1932	5,352,078	3,829,686
1913	6,702,449	3,381,692	1933	5,044,179	4,212,866
1914	6,866,077	2,937,957	1934	5,970,517	5,064,807
1915	6,164,400	2,776,812	1935	4,480,079	4,407,721
1916	7,442,452	4,023,692	1936	6,241,404	5,814,440
1917	6,354,635	5,283,000	1937	7,715,962	7,587,013
1918	6,302,677	7,207,840	1938	5,721,011	5,759,996
1919	5,699,306	5,892,679	1939	6,779,592	6,752,222
1920	6,421,739	8,347,271	1940	8,431,656	8,000,225
1921	6,640,334	7,600,711	1941	10,515,940	9,936,898

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

GLASS SAND

Pennsylvania's leading position as glass maker is due in part to the availability within the State of large tonnages of easily mined high grade silica sands. These sands are derived from the disintegration of the Oriskany sandstone and the Pottsville sandstone. Reserves may be said to be inexhaustible. Although the quality of sand employed by the glass manufacturer varies somewhat with the type of glass produced, in general glass sands must be as nearly pure silica as possible. The presence even of traces of iron is objectionable. Sizing is also important and must be reasonably uniform, neither coarse nor fine material being allowed. A common specification requires that 100 percent of the sand pass a No. 20 screen and not more than 5 percent pass a No. 100 screen. Due to the high purity of commercial glass sands they are employed wherever pure silica is in demand, and therefore supply much of the potters "flint" used by the ceramic industries.

Annual production in Pennsylvania tends to stabilize below the half million mark. Value is slightly higher than for common sands, reflecting the additional expense of preparation. However, it is still a very low priced commodity.

BUILDING SAND

Building sands include those for concrete other than pavements, for mortar employed in brick and stone masonry, and for use with gypsum and lime plasters. Clean, strong, durable material is required and it must be free from organic material which may interfere

TABLE 23. GLASS SAND SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA[1]

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1902	356,209	$348,327	1920	394,450	$925,395
1903	301,625	415,714	1921	347,238	468,357
1904	294,333	346,370	1922	280,374	521,142
1905	361,829	482,937	1923	351,420	724,700
1906	342,967	510,910	1924	439,723	932,572
1907	370,977	489,989	1925	418,676	845,455
1908	405,028	484,353	1926	409,067	819,981
1909	281,120	399,707	1927	423,895	814,013
1910	434,147	617,200	1928	451,014	906,350
1911	478,089	668,247	1929	506,812	1,011,063
1912	427,936	517,383	1930	326,760	653,607
1913	513,867	674,073	1931	328,705	632,857
1914	512,718	611,173	1932	277,522	527,308
1915	455,112	550,706	1933	388,365	714,965
1916	534,511	632,702	1934	395,466	734,965
1917	462,972	742,815	1935	440,394	747,892
1918	450,880	1,065,162	1936	434,451	728,485
1919	325,810	797,068	1937	498,874	882,797

[1] Included with "undistributed" in 1938 and later years.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

with the setting action of cement or plaster. Production is directly proportional to activity in the construction industries as is indicated by the figures. It is a typical large-tonnage, low-priced commodity which fluctuates widely with demand.

MOLDING SAND

Molding sand must contain sufficient binding material so that it will retain shape when tamped into place around a pattern. The bonding material may be clay, loam or other foreign material. If material able to produce a bond is not present in the sand as mined it must be added. High silica sands are used for steel molding where high temperatures are encountered. Production varies with activity in metal casting but seldom exceeds 5,000 tons annually.

PAVING SAND

The production of paving sand is a large-bulk, low-cost operation. Production in Pennsylvania at times exceeds two million tons per year. The material is commonly produced in three types: sand for concrete pavements, sand for asphaltic or bituminous pavements, and sand for grouting.

TABLE 24. BUILDING SAND SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1902	173,287	$57,534	1922	2,398,712	$2,230,397
1903	83,062	61,149	1923	3,033,252	2,900,175
1904	740,111	279,880	1924	4,225,100	3,352,585
1905	1,689,100	730,946	1925	4,316,359	3,318,878
1906	2,288,006	808,679	1926	3,994,121	3,036,082
1907	2,288,586	855,567	1927	4,385,810	3,436,976
1908	1,596,610	691,316	1928	3,900,967	3,106,845
1909	2,153,039	892,703	1929	3,452,533	3,300,615
1910	2,245,658	941,327	1930	3,124,854	2,831,032
1911	2,072,830	882,516	1931	1,956,996	1,659,558
1912	1,648,996	789,819	1932	1,076,648	690,852
1913	2,298,640	987,810	1933	845,765	491,929
1914	2,086,256	857,305	1934	1,026,637	777,867
1915	2,395,299	931,140	1935	881,739	685,755
1916	2,706,240	1,223,477	1936	1,202,949	1,098,841
1917	1,996,524	1,319,624	1937	1,320,515	1,252,843
1918	1,537,984	1,529,133	1938	1,160,031	1,112,035
1919	1,517,957	1,289,827	1939	1,430,383	1,311,100
1920	1,963,779	2,266,500	1940	1,754,452	1,528,159
1921	2,335,006	2,691,175	1941	2,565,461	2,184,162

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 25. MOLDING SAND SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1904	628,064	$369,381	1923	781,389	$1,271,174
1905	656,034	396,741	1924	477,087	725,981
1906	555,449	399,091	1925	537,536	792,067
1907	561,980	398,691	1926	631,066	878,798
1908	359,161	262,467	1927	448,586	551,625
1909	540,007	350,975	1928	379,493	561,217
1910	605,340	413,741	1929	432,632	647,879
1911	657,197	451,779	1930	309,533	449,780
1912	792,150	627,532	1931	190,958	259,010
1913	730,224	505,334	1932	96,900	108,694
1914	370,915	280,933	1933	145,466	192,526
1915	554,809	342,782	1934	188,593	281,262
1916	737,385	590,704	1935	198,656	309,531
1917	640,450	696,734	1936	317,481	495,751
1918	1,158,715	953,886	1937	338,531	546,995
1919	512,862	712,460	1938	164,314	254,017
1920	611,930	1,020,927	1939	265,085	413,168
1921	242,810	384,349	1940	334,905	503,536
1922	428,782	584,650	1941	433,853	669,450

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

GRINDING AND POLISHING SAND

Most sands are composed essentially of quartz, a mineral with a hardness of seven in the scale of relative hardness. Sand, therefore, can be used for many grinding, polishing and abrasive operations. It is used for sand blasting, supplying the necessary abrasive to the wire saw in the slate industry and for grinding plate glass to the desired thickness. It is likewise useful in many other similar operations where a cheap efficient abrasive is needed. In Pennsylvania the plate glass industry has been a conspicuous consumer of grinding and polishing sand.

FIRE SAND

Fire or furnace sand is used to line furnace bottoms, particularly those used to make acid open-hearth steel. A material capable of withstanding high temperatures is required. A sand of high silica is, therefore, specified. Production rarely passes the 100 thousand ton mark.

ENGINE SAND

Engine sand is used to improve traction between locomotive wheels and steel rails which may become slippery from water or snow. It is also used in mine and quarry haulage systems. The railroads are by far

TABLE 26. PAVING SAND SOLD OR USED IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1911	259,121	$88,992	1927	2,594,240	$2,001,530
1912	304,288	134,604	1928	2,610,945	1,913,302
1913	283,946	105,498	1929	2,426,304	2,110,870
1914	625,171	235,326	1930	2,278,813	2,118,769
1915	291,599	106,828	1931	1,036,700	901,964
1916	332,368	132,017	1932	637,862	426,579
1917	432,849	356,575	1933	702,367	539,099
1918	348,039	406,932	1934	850,546	685,120
1919	646,816	562,114	1935	727,727	596,124
1920	756,753	725,595	1936	918,157	815,690
1921	776,633	655,627	1937	1,546,527	1,462,997
1922	890,577	854,129	1938	1,237,875	1,252,905
1923	1,088,248	993,937	1939	1,506,060	1,424,265
1924	1,502,227	1,459,762	1940	2,180,597	1,871,796
1925	2,068,622	1,497,546	1941	1,802,290	1,580,348
1926	2,294,898	1,592,072			

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 27. SAND SOLD OR USED BY COMMERCIAL AND NONCOMMERCIAL PRODUCERS IN PENNSYLVANIA

Year	*Grinding and Polishing*		*Fire or Furnace*		*Engine*	
	Net tons	*Value*	*Net tons*	*Value*	*Net tons*	*Value*
1902	....	....	22,470	$25,475	84,457	$68,387
1903	....	....	41,662	40,034	72,440	66,481
1904	....	....	70,037	66,536	70,667	53,521
1905	....	....	75,494	55,790	124,519	90,208
1906	....	....	85,746	52,945	154,387	110,809
1907	....	....	147,789	114,323	194,986	145,935
1908	[1]	....	71,593	50,874	127,967	82,954
1909	[1]	....	143,116	98,113	141,137	109,224
1910	[1]	....	137,256	95,392	229,233	150,659
1911	500,604	$326,490	92,653	62,122	167,203	110,017
1912	679,155	399,881	150,068	111,023	128,162	78,671
1913	451,711	346,685	115,672	90,687	216,151	127,257
1914	418,072	295,963	91,519	61,085	409,875	109,348
1915	232,731	172,806	82,211	59,134	246,220	139,223
1916	331,160	308,472	152,319	161,404	282,865	194,839
1917	480,955	567,013	185,137	175,022	414,315	415,705
1918	460,047	881,799	143,932	211,330	354,190	543,453
1919	483,307	804,108	121,737	129,984	294,927	456,604
1920	427,019	1,105,940	122,931	192,375	333,686	484,249
1921	475,466	900,245	97,319	155,177	298,328	392,621
1922	583,522	936,377	43,600	80,017	205,927	309,885
1923	715,257	1,247,416	81,156	114,376	352,895	515,465
1924	656,956	1,047,186	23,649	42,911	343,510	379,274
1925	722,996	1,016,954	69,559	100,132	328,729	418,396
1926	644,684	938,045	61,207	92,433	319,645	217,823
1927	617,591	730,431	42,910	53,834	360,935	429,858
1928	448,859	509,047	40,809	54,476	353,582	382,499
1929	570,717	664,910	101,373	133,123	328,012	355,027
1930	343,350	348,866	56,180	74,428	299,277	345,686
1931	200,791	325,085	24,578	33,718	233,354	273,124
1932	29,084	39,754	6,452	10,731	174,472	175,670
1933	...	...	31,649	40,854	198,837	192,273
1934	194,682	237,022	33,502	47,534	218,740	232,901
1935	325,997	398,183	61,147	84,233	229,461	253,353
1936	....	....	27,493	44,958	218,820	253,018
1937	381,002	388,022	75,428	84,014	231,989	258,761
1938	120,874	121,710	12,880	23,071	178,354	185,076
1939	190,561	182,944	15,593	25,220	215,603	229,755
1940	223,546	172,484	19,028	30,414	283,754	316,062
1941	....	....	41,893	60,912	327,985	354,943

[1] Not tabulated separately for Pennsylvania.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

the greatest consumers. In general they specify a high silica sand which will not cake and sized between a No. 20 and No. 80 screen. Production fluctuates between 300 and 400 thousand tons annually.

GRAVEL

Although gravel is one of the commonest of mineral products, no accurate definition exists. It is commonly accepted as being granular mineral matter, rounded by wind or water or ice action, varying in size between one-quarter of an inch and 3½ inches. Most of the material of commercial interest has been transported by water. During transportation angularity has been reduced by abrasion and a rough sorting by size has taken place. Production is mostly centered in streams or adjacent terraces. The reworked glacial gravels of the lower Delaware River Valley have been most productive.

The principal market for gravel is in the construction industries, particularly as an aggregate in concrete and in road making. It is a cheap commodity and cannot be shipped long distances. Markets, therefore, are restricted to areas within a radius of economic transportation. Competition with crushed stone,

Table 28. GRAVEL PRODUCED IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1905	833,805	$272,559	1924	(1)	(1)
1906	1,438,923	306,591	1925	(1)	(1)
1907	1,534,029	347,170	1926	(1)	(1)
1908	938,167	239,530	1927	4,943,999	$4,005,406
1909	1,341,705	252,033	1928	4,740,957	3,833,972
1910	1,423,347	367,006	1929	4,814,293	5,400,125
1911	1,377,394	350,243	1930	4,213,452	4,229,300
1912	1,921,425	456,905	1931	4,211,986	2,847,342
1913	1,943,900	429,081	1932	2,964,768	1,753,144
1914	1,766,651	387,845	1933	2,481,556	1,747,436
1915	1,814,902	433,223	1934	2,940,632	1,936,610
1916	2,241,218	734,881	1935	1,470,270	1,183,730
1917	1,721,480	988,879	1936	2,487,539	1,811,383
1918	1,772,840	1,538,487	1937	3,088,283	2,461,775
1919	1,783,625	1,129,028	1938	2,300,791	1,926,289
1920	1,763,789	1,570,409	1939	2,541,876	2,192,118
1921	2,043,352	1,926,078	1940	2,875,621	2,429,854
1922	2,473,108	1,842,088	1941	4,245,005	3,434,613
1923	2,782,926	2,152,376			

[1] No figures available.

Source: *Mineral Resources of the United States* and *Minerals Yearbook.*

Table 29. BUILDING GRAVEL SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1920	984,946	$868,016	1931	1,969,015	$1,833,312
1921	1,068,851	1,097,768	1932	1,038,784	933,908
1922	1,506,650	1,107,579	1933	966,019	894,398
1923	1,826,040	1,388,599	1934	792,717	631,557
1924	2,450,313	1,952,139	1935	729,937	607,808
1925	2,658,404	2,236,534	1936	973,208	798,970
1926	2,737,927	2,503,653	1937	977,126	901,173
1927	2,939,220	2,482,095	1938	810,077	757,590
1928	2,885,858	2,529,239	1939	1,063,890	952,811
1929	2,966,015	3,107,532	1940	1,227,583	1,076,969
1930	2,482,433	2,704,255	1941	2,120,500	1,777,937

Source: *Mineral Resources of the United States* and *Minerals Yearbook.*

Table 30. PAVING GRAVEL SOLD OR USED BY PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1920	705,811	$681,709	1931	2,242,971	$1,014,030
1921	957,125	814,799	1932	1,904,985	810,556
1922	748,599	570,346	1933	1,515,537	853,038
1923	831,940	717,246	1934	2,131,272	1,299,763
1924	1,086,860	945,074	1935	740,333	575,922
1925	1,413,095	1,163,573	1936	1,514,331	1,012,413
1926	1,698,407	1,462,606	1937	2,061,218	1,513,723
1927	1,929,954	1,512,380	1938	1,456,552	1,140,217
1928	1,792,826	1,290,846	1939	1,420,936	1,191,814
1929	1,848,278	2,292,593	1940	1,578,069	1,295,286
1930	1,702,653	1,518,831	1941	2,023,126	1,582,425

Source: *Mineral Resources of the United States* and *Minerals Yearbook.*

which might be described as an artificial gravel, is a common occurrence. Examination of the production record shows that tonnage has tended to stabilize during the past twenty years but has been subject to drastic curtailment during the depression years when construction was far below normal.

SLATE

Slate is a metamorphosed fine-grained silicate rock of sedimentary origin, whose chief distinguishing physical characteristic is a pronounced cleavage in one direction which allows the rock to be split readily into rather thin sheets. This property, plus its hardness and durability, has rendered the rock particularly suitable for roofing purposes. Slate has been extensively utilized in this capacity for the last three centuries.

The slate industry in Pennsylvania has, since the middle of the eighteenth century, provided the State with a steady source of revenue. Pennsylvania slate controls about half of the slate sales in the United States, both in roofing and mill stock, but the actual volume of sales is steadily declining. This decline is chiefly the result of two factors namely, the decline in the slate industry as a whole and the increasing consumer preference for the colored New England slates over the gray Pennsylvania variety.

TABLE 31. VALUE OF SLATE SOLD IN PENNSYLVANIA

Year	*Value*	*Year*	*Value*
1890	$2,011,726	1916	$3,124,743
1891	2,142,905	1917	3,306,704
1892	2,333,000	1918	2,304,647
1893	1,472,275	1919	2,885,072
1894	1,620,158	1920	3,850,267
1895	1,647,751	1921	3,595,386
1896	1,726,318	1922	4,324,294
1897	2,365,299	1923	5,587,670
1898	2,491,756	1924	5,157,868
1899	2,537,022	1925	5,885,179
1900	2,713,598	1926	5,413,177
1901	2,984,264	1927	4,769,432
1902	3,547,322	1928	4,786,355
1903	3,959,906	1929	4,798,200
1904	3,633,246	1930	3,634,258
1905	3,491,905	1931	2,791,752
1906	3,522,149	1932	1,355,684
1907	3,855,640	1933	1,124,014
1908	3,902,958	1934	1,237,477
1909	2,892,358	1935	1,800,733
1910	3,740,806	1936	2,900,013
1911	3,431,351	1937	2,735,744
1912	3,474,247	1938	2,501,477
1913	3,733,581	1939	3,056,853
1914	3,609,959	1940	2,609,801
1915	3,044,269	1941	3,464,348

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

The slate industry is confronted with a 75 to 90 percent waste in the production of finished material. Any industry marketing a low-cost product and having such a high percentage of waste is economically insecure, since any reduction of the market or decrease in market value of the finished product makes production infeasible for all but the most favorably situated producers. Such a market reduction has now occurred because of the encroachment of artificial roofing and mill stock materials whose producers are not handicapped by a waste problem. They are very successfully capturing the market from what was originally a virtual monopoly.

TABLE 32. ELECTRICAL SLATE SOLD BY PRODUCERS IN PENNSYLVANIA

Year	*Square feet*	*Value*
1917	571,150	$49,868
1918	406,514	171,880
1919	302,879	114,933
1920	638,557	441,726
1921	337,186	216,271
1922	422,310	231,274
1923	676,140	453,070
1924	510,850	366,562
1925	488,080	346,513
1926	488,125	327,447
1927	343,050	228,559
1928	340,100	211,588
1929	340,530	219,761
1930	180,470	99,577
1931	95,130	44,420
1932	29,360	17,074
1933	38,850	18,670
1934	36,580	19,022
1935	51,990	24,848
1936	60,660	30,604
1937	60,190	31,181
1938	21,410	10,083
1939	43,970	20,046
1940	48,440	22,110
1941	79,260	35,496

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

The proportion of waste in the production of slate was considerably reduced by the introduction of the wire saw in the Pennsylvania quarries in 1928. Further reduction can undoubtedly be effected by the use of more modern quarrying methods, milling methods, and equipment.

The competition from the colored slates from other States can probably be met by intelligent advertising or by applying color to the Pennsylvania slates. It is obvious that technological utilization of the vast amount of waste slate by making of new materials and

TABLE 33. ROOFING SLATE SOLD BY THE PRODUCERS IN PENNSYLVANIA

Year	Squares (100 sq. feet)	Value
1890	476,038	$1,641,003
1891	507,824	1,741,836
1892	550,000	1,925,000
1893	364,051	1,314,451
1894	411,550	1,380,430
1895	426,687	1,437,697
1896	431,324	1,391,539
1897	657,692	2,034,958
1898	571,256	2,097,735
1899	711,138	2,202,742
1900	788,571	2,277,192
1901	853,028	2,591,625
1902	908,206	3,001,545
1903	871,875	3,378,804
1904	778,825	2,922,259
1905	802,170	2,879,671
1906	755,966	2,710,249
1907	793,466	2,987,740
1908	825,078	3,070,906
1909	626,228	2,281,779
1910	777,190	2,809,593
1911	699,344	2,508,435
1912	716,770	2,528,791
1913	678,396	2,605,882
1914	614,863	2,463,944
1915	574,223	2,142,173
1916	531,342	$2,056,324
1917	457,393	2,110,044
1918	211,196	1,161,545
1919	269,580	1,679,519
1920	220,366	1,746,026
1921	202,605	1,565,109
1922	283,365	2,076,585
1923	300,272	2,373,125
1924	249,450	2,020,986
1925	287,120	2,316,856
1926	263,668	2,127,782
1927	247,120	1,953,076
1928	256,540	2,033,588
1929	251,880	1,967,428
1930	194,700	1,470,669
1931	183,600	1,254,080
1932	86,550	492,917
1933	95,050	537,178
1934	84,690	585,973
1935	144,290	879,209
1936	235,780	1,603,734
1937	219,780	1,561,731
1938	195,560	1,293,426
1939	236,710	1,607,929
1940	216,020	1,444,696
1941	248,980	2,075,490

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 34. STRUCTURAL AND SANITARY SLATE SOLD BY THE PRODUCERS IN PENNSYLVANIA[1]

Year	Square feet	Value
1890	......	$370,723
1891	......	401,069
1892	......	408,000
1893	......	157,824
1894	......	239,728
1895	......	210,054
1896	......	334,779
1897	......	330,341
1898	......	394,021
1899	......	334,280
1900	......	436,406
1901	......	392,639
1902	......	545,777
1903	......	581,102
1904	......	710,987
1905	......	612,234
1906	......	811,900
1907	4,597,884	620,753
1908	3,565,083	498,188
1909	3,389,119	441,464
1910	3,476,526	539,572
1911	4,029,663	574,966
1912	4,101,200	552,929
1913	4,210,515	648,216
1914	3,946,576	580,415
1915	3,555,398	511,872
1916	4,030,781	619,487
1917	3,971,552	710,092
1918	2,824,795	686,999
1919	2,206,697	597,727
1920	2,539,396	878,191
1921	1,646,483	600,753
1922	2,022,210	676,954
1923	2,300,230	776,833
1924	2,203,040	857,602
1925	2,702,760	896,087
1926	2,848,000	997,108
1927	2,705,030	923,888
1928	2,756,410	999,766
1929	3,012,500	1,135,695
1930	2,358,150	822,391
1931	1,771,760	550,005
1932	1,140,750	328,553
1933	821,790	203,934
1934	778,130	216,086
1935	937,920	272,837
1936	1,236,940	349,968
1937	1,165,300	329,141
1938	1,053,000	273,676
1939	922,090	271,425
1940	677,940	204,716
1941	638,680	206,881

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[1] Figures from 1890 to 1920 represent millstock; no quantity figures are available from 1890 to 1906.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

hence opening new markets is necessary if slate is to compete with other materials which have taken advantage of modern scientific advances.

STONE

Stone is used to designate those rocks that are utilized in their natural form with little processing other than shaping or crushing to desired size. Pennsylvania enjoys an endowment of these materials which exhibit an exceptional diversity of composition and color. The production of dimension stone is a fairly substantial industry. Most of the production is obtained from small quarries and is used within a limited radius for architectural purposes. Pennsylvania possesses no dimension stone industries comparable to those based on the granite of Vermont or the limestone of Indiana.

TABLE 35. TOTAL STONE SOLD OR USED BY PRODUCERS IN PENNSYLVANIA

Year	*Net tons (Approximate)*	*Value*
1894	......	$5,245,507
1895	......	5,563,451
1896	......	4,468,857
1897	......	5,486,612
1898	......	5,993,616
1899	......	6,867,265
1900	......	8,111,602
1901	......	10,772,288
1902	......	12,589,202
1903	......	[1] 13,913,220
1904	......	[1] 12,512,099
1905	......	7,956,177
1906	......	8,804,776
1907	......	9,132,372
1908	......	[2] 6,371,152
1909	......	8,125,723
1910	......	8,621,937
1911	......	8,147,505
1912	......	9,144,214
1913	......	10,117,469
1914	......	8,153,413
1915	......	9,310,397
1916	......	11,021,655
1917	......	14,048,158
1918	......	15,783,147
1919	13,262,310	16,529,971
1920	14,296,630	20,615,316
1921	9,022,650	12,378,202
1922	12,731,940	14,591,194
1923	15,679,170	18,997,295
1924	14,559,490	17,966,836
1925	16,124,590	18,870,945
1926	16,628,770	19,157,336
1927	16,015,480	18,999,592
1928	16,546,850	18,871,736
1929	18,169,270	19,956,410
1930	15,137,560	17,822,706
1931	11,123,680	11,926,265
1932	10,842,100	9,264,631
1933	12,802,020	11,660,318
1934	15,251,330	14,501,246
1935	8,570,050	8,895,606
1936	15,814,260	17,900,502
1937	16,091,160	17,251,160
1938	12,134,290	13,045,423
1939	15,743,790	16,906,854
1940	19,277,690	19,855,478
1941	23,506,540	25,013,500

[1] Includes slate.
[2] Includes bluestone.

Many types of stone are crushed to varying dimensions and used as concrete aggregate, railroad ballast and rip rap. The chemical composition of limestone with its ability to neutralize acidity and to supply calcium for slags and other uses increases its utility.

BASALT AND RELATED ROCKS

Basalt and its common variant, diabase, are common rocks in southeastern Pennsylvania. Both are commonly known as trap rock. The diabase ridges composing Seminary Ridge and Little Round Top and Big Round Top on the Gettysburg battlefield are well known. Because of its dark and somber color basalt is not extensively used for building material. Due to its crystalline nature it possesses superior tensile strength and supplies an excellent aggregate for concrete. Production commonly exceeds one million tons annually.

In 1941, 4,480 tons valued at $4,649 were used in dimension form. A more important tonnage for the same year was employed as crushed stone as indicated by the following.

TABLE 36. BASALT AND RELATED ROCKS (TRAP ROCK) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

	Net tons	*Value*
Rip rap	1,630	$1,901
Concrete and road metal	1,067,790	1,013,609
Railroad ballast	250,420	269,046
Other uses	2,500	1,250
TOTAL	1,322,340	$1,285,806

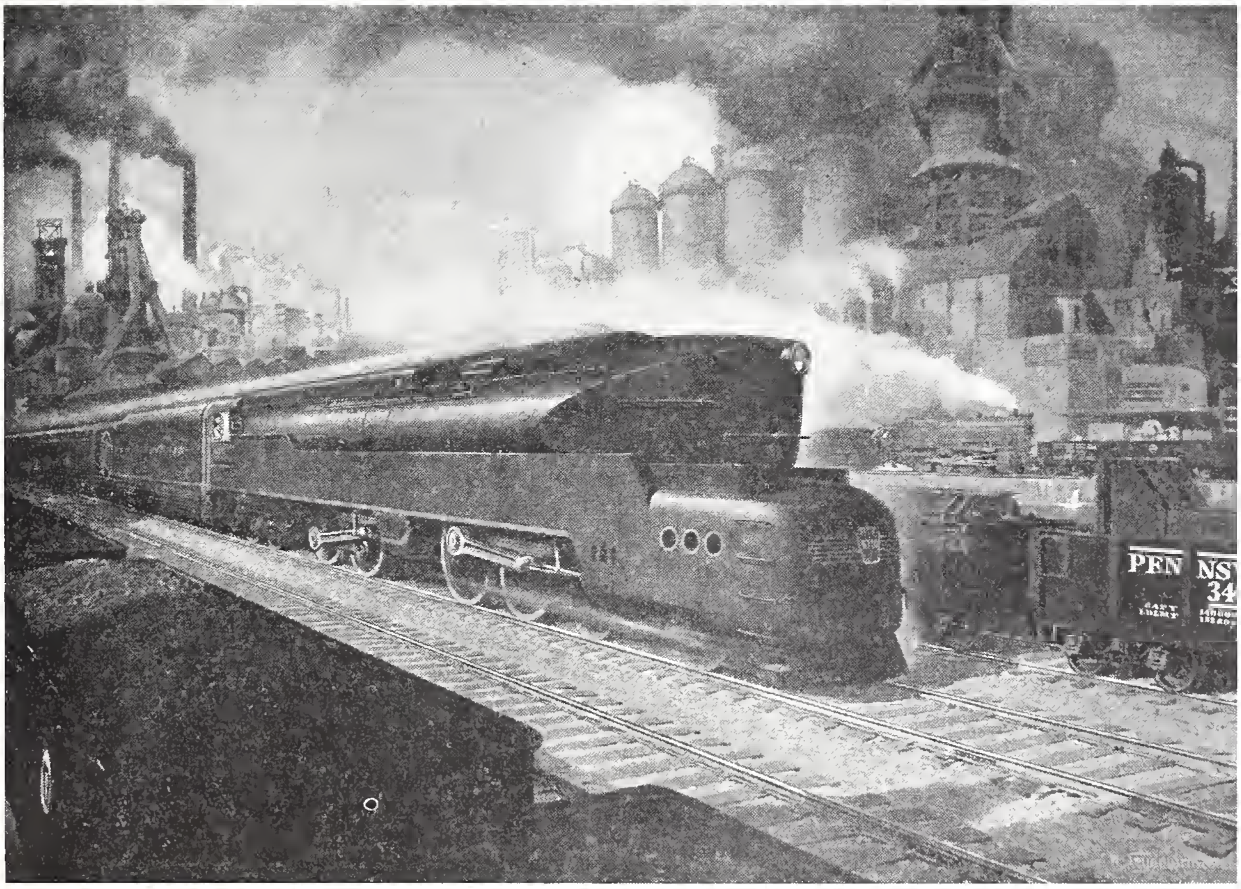
BLUESTONE

Bluestone is actually a variety of sandstone that is produced only in New York and Pennsylvania. Most of it splits easily into thin, smooth slabs. Color variations from blue, gray to green are common. It supplies an excellent flagstone, at one time in extensive use for walks and paving. It has been supplanted by concrete in many cases.

TABLE 37. BASALT AND RELATED ROCKS (TRAP ROCK) SOLD OR USED IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1898		$120,298	1920	1,161,260	$1,704,185
1899		234,474	1921	1,117,940	1,738,890
1900		276,084	1922	1,394,770	1,899,287
1901		288,009	1923	1,384,500	1,940,670
1902		323,943	1924	1,269,190	1,798,564
1903		458,984	1925	1,307,930	1,883,646
1904		429,002	1926	1,472,930	2,068,773
1905		420,229	1927	1,602,210	2,266,435
1906		693,687	1928	1,455,780	2,192,441
1907		760,966	1929	1,443,610	2,143,164
1908		517,909	1930	1,203,370	1,714,137
1909		720,253	1931	693,110	938,264
1910		970,823	1932	630,690	818,847
1911		864,810	1933	548,210	535,093
1912		916,383	1934	729,420	740,486
1913		1,218,918	1935	489,620	508,398
1914		1,076,001	1936	1,028,670	975,379
1915		1,101,778	1937	1,125,100	1,038,550
1916		1,041,203	1938	674,150	618,049
1917		1,178,664	1939	851,820	695,687
1918		1,355,332	1940	975,270	881,616
1919	1,134,400	1,497,526	1941	1,322,340	1,285,806

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*



Freight Transportation
from P. R. R. Painting

TABLE 38. VALUE AND USES OF BLUESTONE PRODUCED IN PENNSYLVANIA

Year	*Building purposes*	*Flagging*	*Curbing*	*Crushed stone*	*Other purposes*	*Total value*
1900		$90,609	$46,227	$19,210	[1] $125,408	$281,454
1901	$103,718	87,008	42,747	47,233	45,651	326,357
1902	177,296	92,469	69,556	90,209	36,282	465,812
1903	323,763	173,701	126,593	45,971	82,462	752,489
1904	287,685	216,251	149,491	29,842	64,146	747,415
1905	292,062	216,435	157,391	38,877	121,396	826,161
1906	268,290	265,481	170,103	54,994	124,096	882,964
1907	210,972	253,523	128,740	54,552	113,574	761,361
1908	186,093	217,690	116,197	6,985	14,933	541,898
1909	159,193	195,525	83,538	70,269	20,281	528,806
1910	138,207	107,846	98,558	47,823	7,558	399,992
1911	92,493	87,769	78,106	17,233	9,290	284,891
1912	114,296	95,223	116,647	9,593	17,702	353,461
1913	118,988	93,198	94,625	23,306	6,446	336,563
1914	49,078	48,239	67,590	14,738	6,128	185,773
1915	43,082	57,455	54,923	4,452	3,002	162,914
1916	31,060	41,729	48,415	4,290	7,672	133,166
1917	40,266	25,901	26,408	....	1,250	93,825
1918	([2])	17,097	9,894	....	2,443	29,434
1919	([2])	38,912	30,138	....	840	69,890
1920	([2])	20,145	31,199	....	32,756	84,100
1921	35,434	35,477	85,637	....	762	157,310
1922	12,789	25,984	64,319	....	19,078	122,170
1923	6,913	46,280	94,915	....	300	148,408
1924	14,115	46,265	101,701	....	4,440	166,521
1925	6,090	56,653	129,736	....	3,476	195,955
1926	11,847	80,012	92,498	....	844	185,201
1927	9,362	95,980	101,299	....	2,387	209,028
1928	7,537	150,824	94,681	....	359	253,401
1929	19,975	124,142	66,628	....	1,345	212,090
1930	31,466	115,480	60,953	....	731	208,630
1931	14,867	57,913	19,269	....	9,420	101,469
1932	4,935	26,192	4,725	....	25	35,877
1933	10,731	13,364	1,590	....	248	25,933
1934	489	26,386	1,000	....	74,896	102,771
1935	356	[3] 11,519	....	....	574	12,449
1936	1,013	39,745	15,992	....	792	57,542
1937	12,385	113,482	5,405	....	290	131,562
1938	6,555	107,779	19,724	....	....	134,058
1939[4]	....	81,958	8,902	....	....	90,860

[1] Including building purposes in 1900.

[2] See other purposes.

[3] Includes curbing.

[4] Separate figures for bluestone not available after 1939; included in sandstone.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 39. GRANITE (DIMENSION STONE) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

		Quantity	*Value*
Construction	*Net tons*	20,500	$47,712
Rubble	*Net tons*	118,690	127,024
Monumental, Dressed	*Cubic feet*	36,000	169,472
Curbing	*Cubic feet*	4,900	2,516
TOTAL	*Net tons*	[1] 143,740	$367,800

[1] Approximate.

TABLE 40. GRANITE (CRUSHED AND BROKEN STONE) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

	Net tons	*Value*
Crushed Stone	365,180	$430,123
Other Uses	13,590	13,141
TOTAL	378,770	$443,264

TABLE 41. GRANITE PRODUCED IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1890	....	$623,252	1916	....	$446,868
1891	....	575,000	1917	....	290,748
1892	....	550,000	1918	....	310,050
1893	....	206,493	1919	215,670	444,330
1894	....	600,000	1920	174,240	472,529
1895	....	300,000	1921	125,150	330,301
1896	....	159,317	1922	231,450	577,443
1897	....	349,947	1923	189,420	599,578
1898	....	237,780	1924	281,500	768,307
1899	....	385,101	1925	308,930	812,810
1900	....	396,271	1926	269,590	692,139
1901	....	[1] 486,008	1927	357,010	843,704
1902	....	[1] 661,062	1928	328,330	677,372
1903	....	[1] 829,535	1929	285,540	598,912
1904	....	471,528	1930	199,290	529,114
1905	....	450,619	1931	116,360	328,546
1906	....	349,453	1932	100,280	242,726
1907	....	366,679	1933	82,530	236,339
1908	....	324,241	1934	145,590	347,343
1909	....	507,814	1935	136,380	314,027
1910	....	478,919	1936	62,880	263,287
1911	....	491,428	1937	48,310	268,859
1912	....	575,680	1938	236,550	426,516
1913	....	1,102,206	1939	324,070	540,584
1914	....	511,013	1940	418,790	615,720
1915	....	506,360	1941	522,510	811,064

[1] Includes trap rock.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

GRANITE

True granites are found in only a few areas in southeastern Pennsylvania. The types available do not appear to be amenable for use in monumental work to the same extent as the highly developed granites of Vermont. In 1941 Pennsylvania granite was distributed as shown in Tables 39 and 40.

LIMESTONE

Limestone is available in Pennsylvania in untold billions of tons. It occurs in a great variety of compositions and structures. Due to its wide distribution and the ease with which it can be quarried and its satisfactory qualifications for many uses it is mined and quarried in large amounts and supplies more tonnage than any other type of stone. The amount of dimension stone recovered is comparatively small as to date no such stone has been discovered comparable to the buff limestone of Indiana so widely employed in architectural work in the Eastern States.

TABLE 42. LIMESTONE (DIMENSION STONE) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

		Quantity	*Value*
Construction	*Net tons*	14,620	$19,911
Rubble	*Net tons*	12,150	12,702
Flagging	*Cubic feet*	9,880	1,479
TOTAL	*Net tons*	[1] 27,590	$34,092

[1] Approximate.

TABLE 43. LIMESTONE (CRUSHED AND BROKEN) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

	Net tons	*Value*
Rip rap	6,400	$7,000
Fluxing Stone	9,409,360	8,185,938
Concrete and Road Metal	5,782,340	5,664,753
Railroad Ballast	364,450	379,370
Agriculture	630,670	1,550,649
Other Uses	1,098,710	1,930,889
TOTAL	17,291,830	$17,718,599

Limestone as a whole has shown a steady gain for many years and indicates the rapid industrial growth of the Commonwealth.

TABLE 44. LIMESTONE SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1890	......	$2,655,477	1916	......	$8,167,639
1891	......	2,100,000	1917	......	10,589,524
1892	.....	1,900,000	1918	......	12,302,255
1893	.....	1,552,336	1919	10,665,500	12,640,411
1894	.....	2,625,562	1920	11,531,540	15,913,109
1895	.....	3,055,913	1921	6,713,240	8,346,138
1896	......	2,104,774	1922	9,736,470	9,848,290
1897	......	2,327,870	1923	12,558,550	13,753,093
1898	......	2,746,256	1924	11,558,110	12,778,612
1899	......	3,088,583	1925	13,033,880	13,630,050
1900	......	3,800,318	1926	13,250,290	13,447,371
1901	......	5,081,387	1927	12,382,070	13,025,863
1902	......	5,420,287	1928	13,048,120	13,075,166
1903	.....	5,775,506	1929	14,525,080	14,024,287
1904	......	5,246,423	1930	12,100,700	12,375,067
1905	......	4,499,503	1931	8,350,060	8,552,692
1906	......	4,865,130	1932	5,989,360	6,110,073
1907	......	5,821,275	1933	6,852,560	6,611,916
1908	......	4,057,471	1934	8,360,800	8,198,685
1909	......	5,073,825	1935	6,993,440	6,826,874
1910	......	5,394,611	1936	11,058,690	10,670,502
1911	......	5,243,045	1937	12,729,540	13,074,333
1912	......	6,017,308	1938	8,158,580	8,910,502
1913	......	6,189,145	1939	10,958,070	11,442,286
1914	......	5,270,458	1940	14,324,060	14,466,360
1915	......	6,367,446	1941	17,319,520	17,752,691

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 45. SANDSTONE SOLD OR USED BY THE PRODUCERS IN PENNSYLVANIA[1]

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1890	......	$1,609,159	1916	......	$1,318,239
1891	......	750,000	1917	......	1,794,919
1892	......	650,000	1918	......	1,543,544
1893	......	622,552	1919	1,098,290	1,661,959
1894	......	349,787	1920	1,210,240	2,108,167
1895	......	500,000	1921	968,660	1,775,148
1896	......	446,926	1922	1,240,560	2,005,125
1897	......	380,813	1923	1,405,330	2,359,306
1898	......	478,451	1924	1,322,260	2,305,743
1899	......	717,053	1925	1,351,140	2,235,726
1900	......	1,050,248	1926	1,502,490	2,625,730
1901	......	2,063,082	1927	1,484,580	2,439,067
1902	......	2,800,108	1928	1,462,570	2,437,440
1903	......	3,255,073	1929	1,696,290	2,767,864
1904	......	2,641,510	1930	1,486,210	2,935,385
1905	....	2,487,939	1931	1,189,320	1,678,959
1906	......	2,724,874	1932	1,347,060	1,067,578
1907	......	2,064,913	1933	985,560	1,120,730
1908	......	1,368,784	1934	1,194,300	1,456,777
1909	......	1,637,794	1935	657,010	837,397
1910	......	1,595,070	1936	23,190	113,492
1911	......	1,333,309	1937	28,430	202,020
1912	......	1,367,601	1938	842,700	1,163,236
1913	......	1,359,533	1939	2,675,040	2,747,186
1914	....	1,140,182	1940	2,681,980	2,831,779
1915	..	1,273,994	1941	2,119,160	2,721,228

[1] Includes bluestone from 1899 on.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

SANDSTONE

Although many attractive sandstones are known to occur in the State, their use in architectural form is limited. Generally, use is localized close to the point of production. The most important uses are for ganister in the manufacture of silica brick and as crushed stone used in concrete. Loosely consolidated sandstones supply the glass sands reported elsewhere.

TABLE 46. SANDSTONE (DIMENSION STONE) SOLD OR USED BY PRODUCERS IN PENNSYLVANIA IN 1941

		Quantity	*Value*
Rough Construction	*Net tons*	10,700	$25,122
Rubble	*Net tons*	6,290	11,602
Curbing	*(Cubic feet)*	4,780	4,673
Flagging	*(Cubic feet)*	103,910	79,564
Net tons	*(approximate)*	26,030	$120,961

CRUSHED STONE

The total crushed stone produced in Pennsylvania has reached a record figure of over ten million tons in 1941. Increase in tonnage has been almost constant since 1900. Aggregate for concrete and road metal constitutes the largest consumption, followed by the metallurgical industries, agriculture, railroads, refractories, paper mills and many smaller users.

TABLE 47. GANISTER ROCK PRODUCED IN PENNSYLVANIA

Year	*Value*	*Year*	*Value*
1927	$43,800	1935	$60,500
1928	225,300	1936	104,400
1929	242,000	1937	130,500
1930	178,300	1938	54,100
1931	84,100	1939	141,200
1932	33,400	1940	159,700
1933	64,900	1941	217,000
1934	40,900	1942	243,100

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

MISCELLANEOUS STONE

Other varieties of rock are used in crushed or broken form as indicated in Table 49. Serpentine, soapstone, gneiss, and mica schist are used locally in relatively small amounts.

BROMINE

The commercial production of bromine in the United States originated in 1846 at Freeport, Pennsylvania. Bromine was recovered from salt brines. Production of unknown magnitude, but probably small, was continued until 1855 or 1856. Operations were then discontinued and no production occurred in the United States until 1866. In that year the industry again became active at Freeport and Tarentum. The

TABLE 48. CRUSHED STONE SOLD IN PENNSYLVANIA

Year	*Net tons*	*Value*	*Year*	*Net tons*	*Value*
1901	.....	$1,172,915	1922	5,058,020	$6,149,333
1902	......	1,715,434	1923	5,174,240	7,129,346
1903	......	2,116,783	1924	([1])	([1])
1904	...	2,189,626	1925	([1])	([1])
1905	3,335,857	1,915,978	1926	([1])	([1])
1906	3,801,654	2,300,435	1927	([1])	([1])
1907	4,073,729	2,553,959	1928	([1])	([1])
1908	3,379,440	2,114,429	1929	7,884,550	9,350,627
1909	4,543,231	2,628,347	1930	8,334,340	9,895,095
1910	4,619,232	2,632,701	1931	6,701,080	7,067,772
1911	4,488,129	2,641,620	1932	5,711,450	5,842,305
1912	3,961,427	2,426,071	1933	5,060,370	5,035,158
1913	4,984,725	3,398,351	1934	6,127,030	6,360,269
1914	4,150,110	2,726,949	1935	3,547,550	3,730,789
1915	4,133,042	2,701,910	1936	8,459,320	10,635,520
1916	3,491,789	2,485,931	1937	7,152,380	7,509,010
1917	2,846,481	2,693,639	1938	7,785,670	7,393,469
1918	2,222,674	2,707,965	1939	6,307,030	6,332,998
1919	3,479,522	4,550,459	1940	7,946,800	7,917,506
1920	3,728,380	5,682,887	1941	10,420,040	10,469,388
1921	4,253,090	6,191,315			

[1] Data not given for individual States.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 49. MISCELLANEOUS VARIETIES OF STONE SOLD OR USED BY PRODUCERS IN PENNSYLVANIA

Year	*Net tons*	*Value*
1917	(1)	$183,803
1918	(1)	265,243
1919	148,300	284,063
1920	219,350	417,326
1921	97,660	187,725
1922	128,690	261,049
1923	141,370	344,648
1924	128,430	315,610
1925	122,710	308,713
1926	133,470	323,323
1927	186,670	400,744
1928	246,370	463,500
1929	218,750	422,183
1930	147,990	269,003
1931	774,830	427,804
1932[2]	2,774,710	1,025,407
1933[2]	4,333,160	3,156,240
1934[2]	4,821,220	3,757,955
1935	293,600	408,910
1936	919,760	1,235,597
1937	862,920	865,745
1938[3]	2,204,970	1,900,048
1939	899,730	1,435,981
1940	832,720	997,700
1941	2,159,800	2,352,684

NOTE: Prior to 1917 miscellaneous varieties of stone were included with the more common kinds of stone to which they were most nearly related.

[1] Included in "undistributed."

[2] Includes road-base material produced by the State of Pennsylvania and used on roads. Quantity and value from 1932 to 1934 consecutively: 2,490,100 tons, $688,783; 4,127,380 tons, $2,546,335; 4,619,280 tons, $3,169,356.

[3] Includes crushed stone used for concrete and road metal in 1938.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 50. TOTAL PRODUCTION OF BROMINE AT FREEPORT AND TARENTUM, PENNSYLVANIA, IN POUNDS[1]

Year	*Freeport*	*Tarentum*
1866	1,484	44
1867	3,843	6,990
1868	3,985	8,757
1869	3,321	8,335
1870	2,295	10,790
1871	249	11,893
1872	....	7,480
1873	....	10,344
1874	....	9,052

[1] U. S. Geological Survey: *Mineral Resources of the United States,* 1887.

Freeport works were abandoned in March 1871, and the Tarentum works in 1874. Production for that period is given in Table 50.

The U. S. Geological Survey reports the production of bromine in Pennsylvania from 1885 to 1890 as shown in Table 51. Production after 1890 is not recorded.

Dilution of the brines resulted in the final abandonment of the industry.

TABLE 51. PRODUCTION OF BROMINE IN PENNSYLVANIA

Year	*Pounds*
1885	60,000
1886	49,549
1887	78,000
1888	100,113
1889	116,922
1890	108,154

FELDSPAR

Feldspar is an essential mineral constituent utilized in the manufacture of glass, chinaware and similar porcelain products. It is now consumed largely by the ceramic industries to the extent of several hundred thousand tons annually. Production in Pennsylvania has been restricted to Delaware and Chester Counties. Part of the material was sold in crude form, the remainder was ground to desired fineness. As late as 1905 Pennsylvania's production accounted for nearly 50 percent of the total for the country. Decline to present day tonnage which is insignificant has been due to exhaustion of all apparent easily mined material. Any future production is dependent upon systematic search for new deposits. An incomplete record follows.

TABLE 52. FELDSPAR SOLD OR USED IN PENNSYLVANIA

	Crude		*Ground*	
Year	*Net tons*	*Value*	*Net tons*	*Value*
1901[1]	4,490	$13,367	14,162	$128,197
1902	6,388	19,923	8,733	95,776
1903	4,485	14,396	9,066	78,509
1904	3,758	9,770	17,319	136,384
1905[1]	4,016	10,940	11,862	107,681
1906	4,604	17,695	13,863	114,435
1907	7,367	28,169	12,266	108,678
1908	3,616	13,226	10,473	90,276
1909	9,103	30,067	9,470	81,399
1910	3,751	12,611	11,340	92,140
1911	2,967	9,078	10,317	92,012
1912	1,947	4,985	7,504	66,302
1913	3,685	19,454	5,944	56,397
1914	2,843	10,162	7,258	61,231
1915	6,395	23,376	....	

[1] Includes Maryland.

TABLE 52. FELDSPAR SOLD OR USED IN PENNSYLVANIA—Continued

Year	*Crude*		*Ground*	
	Net tons	*Value*	*Net tons*	*Value*
1916	7,342	25,899	....	....
1917	10,012	48,786	....	....
1918	4,916	27,651	....	....
1919 [2]	....	....	....	....
1920	8,562	43,649	....	....
1921 [2]	....	....	....	....
1922 [2]	....	....	....	....
1923	2,317	6,355	....	....
1924	1,659	4,763	....	....
1925	1,490	4,722	....	....
1926	1,662	4,492	....	....
1927 [2]	....	....	....	....
1928	2,298	8,851	....	....
1929 [2]	....	....	....	....
1930 [2]	....	....	....	....
1931 [2]	....	....	....	....
1932	28	171	....	....
1933	239	1,442	....	....
1934	72	456	....	....
1935	274	1,847	....	....
1936 [3]	161	828	....	....

[2] Included under miscellaneous stone.

[3] After 1936, data on feldspar are included under miscellaneous stone.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

GRAPHITE

Graphite is a common constituent in many metamorphic rocks which originally contained organic matter. It is reported to have been mined as early as 1758. It has never been a continuous or well established industry. Production has been revived during periods of war when imports from foreign sources have been diminished. This has caused recent activity resulting in production in 1943.

TABLE 53. DOMESTIC CRYSTALLINE GRAPHITE SOLD IN PENNSYLVANIA

Year	*Pounds*	*Value*
1908	356,000	$16,740
1909	2,098,000	116,466
1910	1,392,767	82,194
1911	1,490,000	80,300
1912 [1]	......	......
1913 [1]	......	......
1914 [1]	......	......
1915 [1]	......	......
1916	1,095,716	103,377
1917	804,945	77,475
1918	1,016,900	112,059
1919	484,060	26,003
1920 [2]	......	......

[1] Very little activity reported from 1911 to 1915. See section on graphite in "The Minerals of Pennsylvania," Pennsylvania Topographic and Geologic Survey, 1939.

[2] Included with other States; separate figures for Pennsylvania not available from 1920 on.

SOURCE: *Mineral Resources of the United States.*

OCHER

For many years Pennsylvania has led the country in the production of mineral pigments. Ocher, an iron stained, yellow clay is the most important of these materials. The tonnage produced has declined steadily during the past thirty years. This decline has been due to the development of competitive pigments. A concentrated yellow pigment possessing high tinting strength has been produced from metallic iron. In addition, the recovery of an almost pure hydrous iron oxide from coal mine drainage has become a commercial success. The familiar "sulphur mud," common in streams receiving water from coal mines, is now recovered in substantial tonnages. It can be converted to a red pigment by calcination. The total amount recovered is unknown but probably exceeds ten thousand tons to date.

Other pigments, particularly the brown umbers and sienna, have also been produced in quantity. Iron carbonate ores have been mined and then calcined to produce a red pigment. Some graphite, talc, rottenstone, clay and coal have also been used in limited tonnages. In general the industry has been a comparatively small one in a highly competitive field.

TABLE 54. MARKETED PRODUCTION OF OCHER IN PENNSYLVANIA

Year	*Long tons*	*Value*
1889 [1]	7,073	$103,797
1890 [1]	3,725	61,458
1891 [1]	4,049	56,588
1892 [1]	6,299	90,755
1893 [1]	4,799	71,575
1894 [1]	4,442	47,830
1895 [1]	[2] 6,603	[2] 85,600
1896	2,613	26,818
1897	6,094	81,325
1898	5,345	61,500
1899	6,504	57,245
1900	6,787	84,661
1901	6,814	76,106
1902	8,766	80,259
1903	4,408	34,782
1904	3,640	29,355
1905	6,954	72,360
1906	7,676	79,244
1907	7,185	76,816
1908	6,217	63,035
1909	3,694	45,472
1910	3,252	32,254
1911	2,690	28,101
1912	2,946	28,950
1913	3,513	32,175
1914 [3]	3,392	34,223

[1] Includes umber and sienna.

[2] Includes Missouri and New York.

[3] Separate figures for Pennsylvania not reported after 1914.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

ROTTENSTONE

Rottenstone, the insoluble silicious residue left after the solution of impure limestones, is mined in Pennsylvania in small quantities. It serves both as a gray pigment and as a fine abrasive. It is useful as a filler and as a polishing agent. Production is relatively small and in recent years has not exceeded 250 tons annually.

SALT

The production of salt is one of the oldest mineral industries in Pennsylvania. It is regrettable that a more accurate record of the industry is not available. Salt was the only preservative available to the pioneer and its service in the conservation of meat and other perishable foods was immeasurably more important than at present. All production was obtained by the evaporation of natural brines. Salt wells were numerous along the Allegheny and the Kiskiminetas. By 1843 the industry was well established and drilling operations were carried to a depth of 700 feet. The drilling technique developed in the operation of these wells was later adapted to the production of petroleum. In 1880 sixteen establishments with a capitalization of $234,500 were reported to exist. Nineteen wells with an average depth of 883 feet were in operation. Coal was the common fuel used to evaporate the brine and 55,750 tons valued at $37,141 were used that year. The brines finally became too dilute for profitable treatment and all operations were abandoned in 1914.

A very incomplete record of production follows.[1]

TABLE 55. SALT PRODUCTION IN PENNSYLVANIA

Year	*Barrels 280 pounds*	*Value*
1880	170,290	$177,415
1892	25,571	10,741
1893	280,343	136,436
1894	203,236	83,750
1895	157,243	67,411
1896	198,596	56,717
1897	164,287	45,107
1898	154,287	46,000

[1] Salt Resources of the United States. Bulletin 669. U. S. Geological Survey.

WATER

Water is perhaps the best known but least appreciated of all minerals. Its collection and distribution is one of the State's leading industries, as is demonstrated by the accompanying figures showing a capital investment of nearly half a billion dollars.

The growth of population in our urban areas has made the problem of supplying a sufficient quantity of potable water increasingly difficult. Moreover, a large supply of water is a basic requirement for many industries. The insurance of an adequate supply is indispensable in most plans for future industrial expansion or relocation.

TABLE 56. PRIVATE AND MUNICIPAL WATER SUPPLY COMPANIES IN PENNSYLVANIA

Year	*Capital*	*Employes*	*Compensation*	*Quantity sold*[1] *(M Gallons)*	*Value of sales*[2]
1922	$264,576,083	7,365	$8,502,994	165,075,121	$29,320,370
1923	272,990,228	7,032	8,546,462	198,748,132	31,784,854
1924	282,697,975	7,220	9,454,778	198,485,712	33,092,501
1925	284,868,534	7,940	9,623,004	201,342,918	34,212,682
1926	317,096,309	7,731	10,148,749	277,135,407	37,009,325
1927	340,098,887	7,880	10,503,900	245,977,117	37,066,350
1928	370,221,550	7,918	10,279,302	241,313,640	38,544,736
1929	388,054,412	7,492	10,109,395	244,813,476	39,935,479
1930	404,104,870	7,439	9,826,467	236,144,392	40,145,588
1931	418,517,342	7,343	9,255,387	217,944,989	40,610,413
1932	423,200,445	6,432	7,782,909	191,987,492	38,947,292
1933	425,407,099	6,068	7,126,455	157,046,832	36,625,942
1934	431,472,966	6,388	7,743,365	167,737,618	38,670,760
1935	437,127,862	7,150	7,830,763	195,047,949	40,243,454
1936	441,157,684	8,084	8,669,809	223,575,830	41,232,031
1937	434,247,464	7,467	8,732,277	225,319,348	41,217,022
1938	434,467,798	7,536	8,862,491	204,439,417	39,362,745
1939	462,468,774	7,220	9,041,607	216,945,347	41,097,616
1940	465,465,072	7,092	9,271,107	238,753,822	42,159,551
1941	467,510,658	6,740	10,640,944	258,087,111	44,090,367

[1] Does not include free water furnished nor unmetered service.

[2] Includes metered and unmetered service.

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

MINERAL WATER

The bottling of special waters at springs was at one time a well organized industry. The mineral content varied widely in composition and in some cases was believed to be beneficial in the treatment of certain disorders. This industry has declined during the past twenty years and records have not been kept. The total is now believed to be insignificant. As a record of the past importance of this industry in the mineral output of the State, the following figures are included.

TABLE 57. PRODUCTION OF MINERAL WATERS IN PENNSYLVANIA

Year	*Gallons*	*Value*
1889	275,700	$65,163
1890	309,420	64,676
1891	485,250	73,376
1892	1,324,100	323,164
1893	1,065,800	247,420
1894	1,108,224	160,406
1895	1,594,875	173,884
1896	727,682	146,652
1897	1,007,995	215,463
1898	1,300,541	321,199
1899	1,542,800	340,254
1900	......	......
1901	1,892,885	380,519
1902	4,567,260	1,124,532
1903	1,522,860	357,579
1904	743,050	90,465
1905	1,322,594	194,113
1906	1,506,286	280,054
1907	1,287,063	235,807
1908	1,430,489	180,889
1909	2,177,967	240,856
1910	2,536,337	221,685
1911	2,327,732	216,819
1912	2,192,106	204,906
1913	2,163,931	190,459
1914	2,457,626	213,752
1915	2,136,218	174,798
1916	1,671,637	145,133
1917	1,603,090	147,021
1918	1,400,456	123,436
1919	872,595	83,583
1920	641,440	66,945
1921	730,252	74,490
1922	824,988	81,435
1923[1]	807,522	84,945

[1] No canvass after 1923.

SOURCE: *Mineral Resources of the United States.*

IRON ORES

Pennsylvania became the center of the iron and steel industry of the United States and the world because of the abundant deposits of iron ores together with plentiful supplies of limestone and especially fine sources of fuel. Charcoal from its forests, anthracite, and, later, fine bituminous coking coal furnished fuel and reducing agents that are unsurpassed. Added to these advantages are close proximity to the markets where steel and iron are used in large tonnages.

The iron industry developed in small units, scattered all over the ore-producing regions, and, later, centered in more favorable localities. The ores were of all kinds, with a large proportion of quality well adapted to the making of high-grade iron. When the Bessemer process developed, many of these ores were found low enough in phosphorus and sulphur to be suitable for that process.

Prior to 1860 the iron ores of Pennsylvania, together with those of New York and New Jersey, constituted the chief dependable source in the country.

TABLE 58. IRON ORE MINED BY VARIETIES IN PENNSYLVANIA[1]
(Gross tons)

Year	*Hematite*	*Brown ore*	*Magnetite*	*Carbonate*	*Total*	*Value*
1880	267,572	1,009,550	498,146	176,227	1,951,495	. .
1889	162,957	496,555	860,916	39,806	1,560,234	$3,063,534
1890	143,745	415,779	765,318	36,780	1,361,622	......
1891	162,683	363,894	727,299	19,052	1,272,928	......
1892	163,307	229,700	685,986	5,054	1,084,047	2,197,028
1893	57,633	158,376	480,164	1,812	697,985	1,374,313
1894	25,324	117,149	389,581	33	532,087	643,349
1895	29,606	239,153	628,999	2,582	900,340	997,719
1896	24,030	226,669	494,517	2,568	747,784	920,916
1897	19,515	256,573	441,556	6,098	723,742	851,079
1898	13,975	142,725	614,818	1,564	773,082	877,365
1899	38,331	152,468	815,771	2,757	1,009,327	1,991,772
1900	44,653	232,370	600,066	595	877,684	1,890,100
1901	42,381	226,699	771,351	253	1,040,684	1,561,620
1902	20,441	185,846	616,645	......	822,932	1,225,453
1903	15,420	202,542	426,637	......	644,599	1,062,455
1904	5,286	164,206	227,615	......	397,107	611,211
1905	4,425	166,435	637,857	......	808,717	1,060,162

TABLE 58. IRON ORE MINED BY VARIETIES IN PENNSYLVANIA—Continued

Year	*Hematite*	*Brown ore*	*Magnetite*	*Carbonate*	*Total*	*Value*
1906	8,854	134,027	806,548	.....	949,429	1,246,267
1907	19,403	113,076	704,808	......	837,287	1,298,717
1908	26,162	73,001	343,998	......	443,161	572,346
1909	5,144	80,715	581,030	......	666,889	792,672
1910	846	106,544	632,409	......	739,799	911,847
1911	9,792	50,394	454,743	......	514,929	539,553
1912	10,557	30,371	476,153	......	517,081	481,353
1913	(2)	34,041	455,015	......	489,056	589,038
1914	3,300	23,560	379,466	......	406,326	399,639
1915	(2)	22,552	340,757	......	363,309	333,697
1916	......	16,031	543,400	......	559,431	702,633
1917	......	4,927	541,773	......	546,700	873,320
1918	......	3,163	519,437	......	522,600	982,173
1919	......	10,268	616,899	......	627,167	1,340,219
1920	......	1,892	728,751	3,740	734,383	1,406,929
1921	......	974	142,966	2,709	146,649	288,955
1922	......	861	776,719	3,256	780,836	1,022,756
1923	......	1,284	988,641	3,516	993,441	2,264,485
1924	......	1,014	803,189	3,005	807,208	1,881,122
1925	......	1,039	952,623	2,293	955,955	2,149,800
1926	......	1,140	1,092,150	2,215	1,095,505	2,483,056
1927	......	......	1,167,942	2,493	1,170,435	2,559,916
1928	......	......	1,022,080	1,790	1,023,870	2,411,114
1929	......	......	1,090,238	1,775	1,092,013	2,382,839
1930	......	......	963,635	1,003	964,638	1,850,661
1931	......	......	367,299	818	368,117	913,163
1932	......	1,640	100,721	477	102,838	157,400
1933	......	640	263,227	499	264,366	650,664
1934	......	864	523,793	640	525,297	1,052,770
1935	......	......	978,951	687	979,638	1,861,000
1936	......	......	1,131,682	533	1,132,215	[3] 2,208,908
1937 [3]	......	......	2,624,512	532	2,625,044	5,823,286
1938 [3]	......	......	2,120,823	448	2,121,271	5,867,320
1939 [3]	......	......	2,713,141	463	2,713,604	7,403,750
1940 [3]	......	......	2,899,986	513	2,900,499	8,172,955
1941 [3]	......	3,000	3,300,451	606	3,312,610	9,678,564

[1] Figures classed as production to 1910; after that classed as marketed. Figures before 1911 probably represent marketed production. Value for years 1911 to 1940 changed to "Shipped from Mines."

[2] Included in brown ore.

[3] New York figures included.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

The discovery of high grade ores in Michigan in 1844 and the later discovery of great deposits in Minnesota and Wisconsin in succeeding years brought a new era in the production of iron ore and gave a severe blow to iron mining in Pennsylvania. The easy mining of these "Lake" ores stimulated the development of large scale mining, transportation, and handling methods to such an extent that the widely scattered ores of Pennsylvania had greater and greater difficulty in competing. This, added to the comparatively small scale of operation, and cruder methods of working and beneficiation, placed mines of this type under an increasing handicap which became insurmountable as time went on.

Only a few mines with exceptional advantages of either location or quality of ores survived this period, and for many years the high grade magnetite ores of Cornwall, Warwick and French Creek were worked. The Cornwall mines are a notable exception. Magnetite has been mined for over 200 years, and modern methods and a favorable location have increased production until it ranks among the leading mines of the country. A partial record of early production at Cornwall is given in Table 59.

The early iron miners and furnace operators made an immeasurable contribution to the iron and steel industry of today in that they developed a body of skilled labor and a knowledge of the production and treatment of ores which has been handed down and expanded through successive generations.

TABLE 59. PRODUCTION OF IRON ORE AT THE CORNWALL ORE HILLS, CORNWALL, PENNSYLVANIA

	Long Tons
From 1740 to Feb. 1864	2,518,910
1864 (11 months)	165,915
1865	114,803
1866	216,660
1867	202,755
1868	165,843
1869	173,429
1870	174,408
1871	176,055
1872	193,317
1873	166,782
1874	112,429
1875	98,925
1876	137,902
1877	171,589
1878	179,299
1879	268,488
1880	231,173
1881	249,050
1882	309,681
1883	363,144
1884	412,320
1885	508,864
1886	688,054
1887	667,210
1888	722,917
1889	769,020
1890	686,302
Total	10,845,244

SOURCE: *Mineral Resources of the United States,* 1890, p. 29.

PIG IRON

Pig iron is a rather impure form of iron manufactured from iron-bearing ores in the blast furnace. This impure iron is further refined in other furnaces to produce steel, or is melted with steel in still other types of furnaces to produce cast iron. Thus, pig iron may be regarded as the life blood of our modern way of life, which is largely based on steel and iron products.

In the early history of our country, people settled along the Atlantic seaboard and worked the iron-bearing ores of this region to fashion their iron products. Pennsylvania produced a large proportion of these products because of the location of several good deposits of ore within her borders. Remains of some of the old furnaces used about the period of the Revolutionary War are still standing in various parts of the State. Under the pressure of war interest in these deposits has been renewed.

A study of the accompanying table will show that variations in the production of pig iron coincide with many interesting periods in our history. The years of war, prosperity and depression, and progress of our inventive abilities are all reflected here. The use of steel in large tonnages waited upon the development of processes which could make steel in these large tonnages. When these processes were devolped in the latter part of the nineteenth century, the production of pig iron began to increase steadily to furnish the necessary impure material that is refined in steel making. At this time Pennsylvania was producing about 50 percent of the nation's total production of pig iron. As the nation expanded westward and developed industrially, the production of both the State and Nation progressed steadily. Enormous new deposits of iron ore were discovered in Michigan and Minnesota and new centers of pig iron production developed in other States, particularly Illinois, Indiana, and Ohio. As a consequence of this the quantity of pig iron produced in Pennsylvania as compared to that produced in the nation as a whole dropped off somewhat to 40 percent in 1910.

The effect of World War I on the State's production is noted in the figures for 1914, 1915 and 1916. The production practically doubled over this period and maintained a high level during the war years. As business slackened directly following the war (1921-1922), production fell off correspondingly. This was followed by an increase coinciding with the prosperity of the following years and reaching its peak in 1928 and 1929. Thereafter there was a sharp decrease reaching an extreme low in 1932 when the State was producing no more pig iron than was being produced in the period around 1885. Naturally this decline was general in other States, in line with business conditions. As business showed an upward swing in 1937 so too did pig iron production in the State only to have both fall off again in 1938. The final figures in the table for 1940 and 1941 again show the effect of war. A large part of the world was engaged already in conflict and pig iron production was rising steadily in keeping with the Nation's role as the arsenal of democracy. It is safe to say that these figures have increased since 1941 with our entry into the war and the global nature of the struggle.

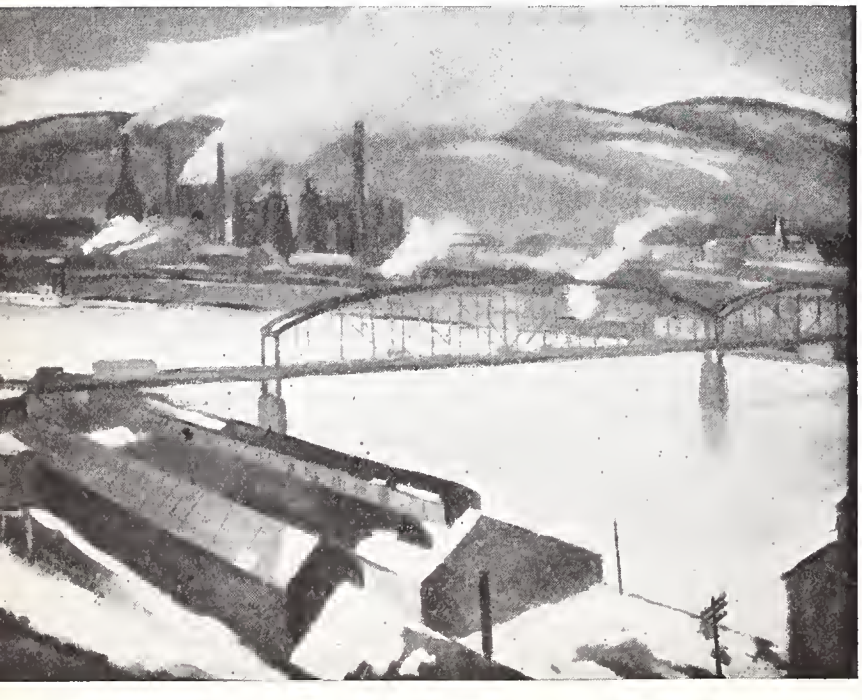
The percentage of the Nation's production manufactured in Pennsylvania has continued to decline slightly. This is probably due not so much to actual decrease of the manufacture within the State as it is to increase of manufacture in other areas. It is apparent from the table that the State was at as high a level in 1940 and 1941 as it was in the years of the first World War, although the monetary value was not as high. Pennsylvania has maintained this production level, despite the fact that most of her ore is imported from outside areas, because of the close proximity of the right types of coal for making the coke fuel used in the blast furnace. It has been more feasible to bring the ore to the coke than the reverse and hence the State, with a plentiful supply of labor for the industry, has maintained her position.

TABLE 60. QUANTITY AND VALUE OF PIG IRON PRODUCTION IN PENNSYLVANIA[1]

Year	*Gross tons*	*Value*
1872	1,251,337	....
1873	1,240,690	....
1874	1,083,154	....
1875	857,932	....
1876	901,440	....
1877	1,029,782	....
1878	1,198,779	....
1879	1,435,503	....
1880	1,859,929	....
1881	1,956,059	....
1882	2,186,836	....
1883	2,356,153	....
1884	2,129,823	....
1885	2,183,479	....
1886	2,940,437	....
1887	3,289,838	....
1888	3,204,630	....
1889	3,733,252	....
1890	4,415,329	....
1891	3,952,387	....
1892	4,193,805	....
1893	3,643,022	....
1894	3,370,152	....
1895	4,701,163	....
1896	4,024,166	....
1897	4,631,634	....
1898	5,537,832	....
1899	6,558,878	....
1900	6,365,935	....
1901	7,343,257	....
1902	8,117,800	....
1903	8,211,500	....
1904	7,644,321	....
1905	10,579,127	....
1906	11,247,869	....
1907	11,348,549	$234,952,000
1908	6,987,191	111,385,000
1909	10,918,824	175,429,000
1910	11,014,652	174,486,833
1911	9,581,109	136,328,507
1912	12,437,685	181,569,299
1913	12,871,349	197,726,314
1914	9,267,197	127,686,331
1915	12,779,974	174,926,891
1916	16,351,131	293,437,782
1917	15,423,262	460,677,474
1918	14,701,252	465,859,029
1919	11,901,992	307,824,587
1920	13,472,814	448,251,415
1921	6,072,196	148,350,285
1922	9,732,024	221,581,288
1923	13,898,624	347,679,274
1924	10,962,288	237,052,035
1925	12,537,809	258,140,674
1926	13,142,528	263,238,184
1927	11,145,334	212,179,275
1928	12,289,455	216,425,084
1929	14,058,194	257,154,601
1930	9,734,591	176,521,843
1931	5,099,016	86,877,965
1932	2,069,553	32,764,148
1933	3,952,862	62,797,008
1934	4,173,412	75,383,683
1935	5,549,538	102,027,692
1936	9,379,615	176,552,170
1937	11,036,467	239,838,942
1938	4,684,017	101,266,844
1939	8,979,649	186,302,533
1940	16,320,009	282,666,561
1941	18,301,881	344,298,435

[1] Figures classed as production to 1910; after that classed as marketed. Figures before 1911 probably represent marketed production. Beginning 1915 changed to "Shipped from blast furnaces."

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*



Blast Furnace
by Richard Crist

BESSEMER STEEL

The Bessemer process for converting molten pig iron to steel by passing a current of air through the molten metal was the first successful process for producing large quantities of steel cheaply and quickly. As such its introduction was directly responsible for the rapid expansion in the use of steel and made possible much of the industrial development of the latter half of the nineteenth century. Toward the end of the nineteenth century the process began to be replaced in the United States by others, principally the basic open-hearth process for two reasons, first, because the open-hearth process is such that a greater degree of control over the metallurgical quality of the steel produced is more readily achieved; and secondly, the basic open-hearth is not restricted to low-phosphorus pig iron as a raw material. The available iron ores of the United States are predominantly high-phosphorus ores, whereas pig iron suitable for refinement by the Bessemer process must be made from low-phosphorus ores, which command a somewhat higher price. Further, the amount of scrap which may be used in the Bessemer process is limited to a small fraction of the total charge whereas the open-hearth scrap may be varied over a wide range to take advantage of the relative availability and cost of scrap and pig iron.

As a result of these factors the Bessemer production of both Pennsylvania and the United States as a whole has decreased almost continuously since 1900 except for war periods. The advantages mentioned above are offset to some degree by the fact that the process still remains the most rapid method for producing steel from pig iron. As such, interest in it has recently been revived and considerable progress has been made in devising means for bringing the process under better control. Further, it now appears feasible to use high-phosphorus pig iron as a raw material and produce a low-phosphorus steel by special treatment of the converter product. With continued technological study and development it may well be that the trend of decreasing production will be reversed.

The production figures in the following table do not include steel produced by the "duplex" process, in which high-phosphorus pig iron is first partially refined in the Bessemer converter and then dephosphorized and finished in the basic open-hearth. Steel so produced is reported as basic open-hearth tonnage. If this tonnage were credited to the Bessemer process, the values for the period since 1936 would be increased by some 60 percent.

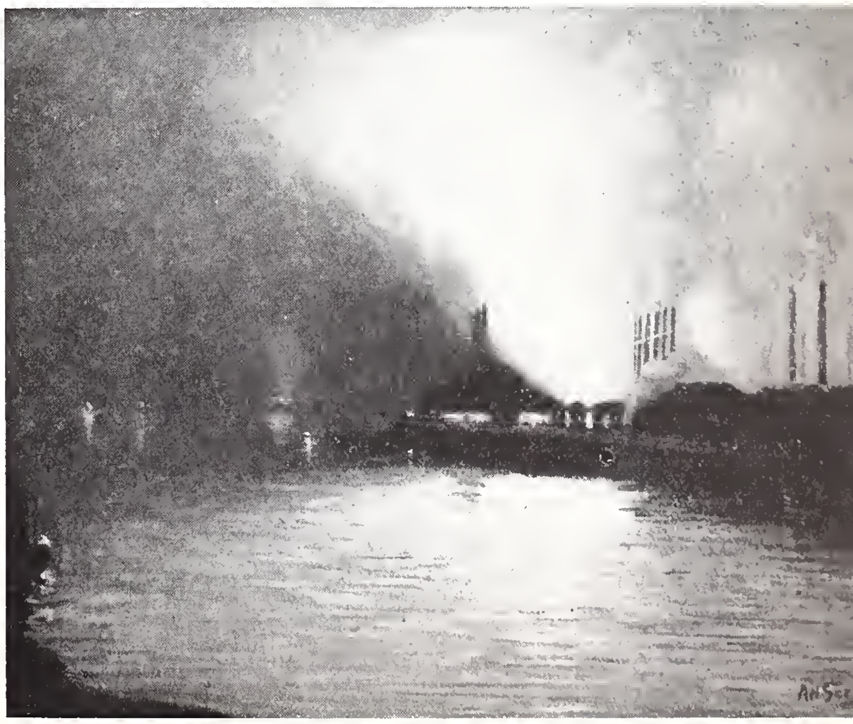
TABLE 61. BESSEMER STEEL INGOTS AND CASTINGS PRODUCED IN PENNSYLVANIA AND THE UNITED STATES
(Gross tons)

Year	*Pennsylvania*	*United States*
1898	3,402,254	6,609,017
1899	3,968,779	7,586,354
1900	3,488,731	6,684,770
1901	4,293,439	8,713,302
1902	4,209,326	9,138,363
1903	3,909,436	8,592,829
1904	3,464,650	7,859,140
1905	4,491,445	10,941,375
1906	4,827,725	12,275,830
1907	4,351,841	11,667,549
1908	2,106,382	6,116,755
1909	2,845,602	9,330,783
1910	2,975,750	9,412,772
1911	2,338,813	7,947,854
1912	3,157,928	10,327,901
1913	2,954,818	9,545,706
1914	2,014,526	6,220,846
1915	2,507,243	8,287,213
1916	3,444,163	11,059,039
1917	3,537,094	10,479,960
1918	3,281,941	9,376,236
1919	2,851,402	7,271,562
1920	3,279,023	8,883,087
1921	1,665,456	4,015,938
1922	2,474,956	5,919,298
1923	3,115,840	8,484,088
1924	2,210,868	5,899,590
1925	2,354,231	6,723,962
1926	2,420,719	6,934,568
1927	2,108,483	6,191,727
1928	2,293,085	6,620,195
1929	2,427,490	7,122,509
1930	1,732,545	5,035,459
1931	786,767	3,023,446
1932	233,215	1,532,076
1933	598,672	2,428,791
1934	570,817	2,162,357
1935	764,403	2,835,031
1936	952,971	3,458,457
1937	830,440	3,449,927
1938	348,060	1,880,661
1939	990,251	2,999,032
1940	1,219,658	3,311,226
1941	1,756,053	4,980,421

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

OPEN-HEARTH STEEL

Since the development of the basic open-hearth process for making steel, near the end of the nineteenth century, this versatile process has largely displaced the more rapid but less precisely controlled Bessemer process in this country. The open-hearth method, in which the molten raw iron is refined by oxygen which



Bessemer Blower at Night
by A. H. Gorson

must pass from the furnace atmosphere through a protecting layer of liquid slag, offers certain advantages which have given it first place in steel production. Among these are (1) a protracted refining period during which the composition of the metal can be satisfactorily adjusted to meet a desired analysis; (2) the ability to make good steel from raw materials high in phosphorus (basic furnace); and (3) the possibility of making 100 or 200 tons, or even more, of steel of one analysis. The predominance of the basic open-hearth process in the American steel industry is seen by examining the Nation's production in a recent year. Of the 1941 production of steel ingots-plus-castings, 88.5 percent was made by the basic open-hearth process, and 1.3 percent by the acid open-hearth process, the remainder being accounted for by the Bessemer, electric, and crucible processes in descending order.

In the accompanying table, the open-hearth production of Pennsylvania is compared with that of the Nation for a period of 42 years. Interesting facts of the history of the past four decades are reflected in the figures. In 1900, when the steel industry was still largely concentrated in Pennsylvania, this State produced 80 percent of the country's open-hearth steel. But as the industrial growth spread westward and new steel-producing areas developed in other States (notably Ohio, Indiana, Illinois and, more recently, on the Pacific Coast), Pennsylvania's portion of the national production fell slowly, despite an increase of several hundred percent in the State's actual output. By 1906, the State's production was almost three times that of 1900 but was only 70 percent of national production. The proportion fell to 51 percent in 1916 and has been less than 50 percent since 1917. In 1930 the relation stood at 36 percent and has since not exceeded 33 percent. In 1941 Pennsylvania made 31 percent of the country's open-hearth steel, still far more than the fraction made by any other State.

Besides the above general trend with time, the table also shows the influence of occasional great disturbances to the Nation's economy. The First World War caused a notable increase in the State's production from 1915 to 1918, which was followed by a precipitous drop in the short depression of 1921. The boom which followed led to the high production of 17.5 million tons by Pennsylvania in 1929, a record not surpassed until World War II. Very obvious is the deep valley of the long depression of the 1930's which reached its nadir in 1932, during which year Pennsylvania produced less open-hearth steel than in 1901. The variable production attending the short business spurt of 1936-37, followed by another sag, recalls the stimulative efforts of Government and the sociological trends of the time. Since 1939, any other factors affecting production are largely obscured by the dominating influence of World War II.

The figures of the table include open-hearth steel castings made by companies which also made steel ingots; but in recent years such castings have required only about 0.4 percent of the total open-hearth tonnage. The given data also include the steel made by the "duplex" process, in which the metal receives a partial treatment in the Bessemer converter and is

TABLE 62. OPEN-HEARTH STEEL INGOTS AND CASTINGS PRODUCED IN PENNSYLVANIA AND THE UNITED STATES

(Gross tons)

Year	*Pennsylvania*	*United States*
1899	2,393,811	2,947,316
1900	2,699,502	3,398,135
1901	3,594,763	4,656,309
1902	4,375,364	5,687,729
1903	4,442,730	5,829,911
1904	4,306,498	5,908,166
1905	6,471,818	8,971,376
1906	7,718,213	10,980,413
1907	7,868,353	11,549,736
1908	5,322,229	7,836,729
1909	9,400,287	14,493,936
1910	10,153,816	16,504,509
1911	9,594,914	15,598,650
1912	12,408,109	20,780,723
1913	12,522,227	21,599,931
1914	9,854,038	17,174,684
1915	13,245,393	23,679,102
1916	16,030,251	31,415,427
1917	16,284,102	34,148,893
1918	15,574,101	34,459,391
1919	12,692,112	26,948,694
1920	14,184,477	32,671,895
1921	6,408,043	15,589,802
1922	11,583,812	29,308,983
1923	14,428,187	35,899,657
1924	12,243,713	31,577,350
1925	14,021,750	38,034,488
1926	15,622,857	40,691,979
1927	13,708,156	38,068,335
1928	15,261,713	44,113,956
1929	17,504,807	48,352,888
1930	12,488,175	35,049,172
1931	7,384,091	22,509,566
1932	3,506,451	11,907,330
1933	5,733,772	20,381,672
1934	6,477,890	23,531,105
1935	7,850,710	30,715,429
1936	12,913,903	43,536,128
1937	14,561,700	46,272,303
1938	7,072,157	25,964,300
1939	12,162,743	43,223,036
1940	16,490,330	54,975,967
1941	20,542,096	66,419,303

SOURCF: *Mineral Resources of the United States* and *Minerals Yearbook.*

then transferred to the basic open-hearth furnace for finishing. In the last years of record, some two million tons of steel annually have been made in this way by the whole country.

FERRO-ALLOYS

A ferro-alloy is an alloy of iron containing enough of the element which gives the alloy its name to make it useful as a source of that element in the manufacture of steel. Such alloys are prepared to facilitate the addition of a determined weight of the alloying element to a batch of molten iron or steel. The addition may serve as a refining agent or as a constituent of the finished steel, or both. The concentration of the alloying element may range from 15 percent or so in one alloy to more than 80 percent in another, depending upon the element, upon the specific use to which the alloy is put, and upon the steel-making practice.

The first ferro-alloys of consequence were spiegeleisen, containing some 20 percent of manganese; ferromanganese, the most common variety of which at present contains about 80 percent of manganese; and ferrosilicon, of which many concentrations are used. These alloys, being made in the iron blast furnace, were for many years listed as part of pig iron production. In 1901 spiegeleisen production in America predominated, and it continued to exceed the combined tonnages of ferrosilicon and ferromanganese until 1909. After 1912, ferromanganese and ferrosilicon were about equal in tonnage and by 1927 spiegeleisen had become a poor third.

After the introduction of the electric furnace into this country in 1909, it became easier to make ferroalloys rich in the companion element. As the variety of alloy steels increased with the growing knowledge of steel making, so the variety of ferro-alloys expanded until now the list includes ferrochromium, ferromolybdenum, ferrovanadium, ferrotitanium, and others.

Steel production in the United States in 1940 was 91 percent greater than in 1912. Ferro-alloys produc-

TABLE 63. FERRO-ALLOYS PRODUCED IN PENNSYLVANIA AND THE UNTED STATES[1]

Year	*Pennsylvania*		*United States*		*Percentage of U. S. total*[2]
	Gross tons	*Value*	*Gross tons*	*Value*	
1911	....	....	253,375	$8,377,832	
1912	203,844	$9,523,815	328,685	12,223,776	62.0
1913	212,719	10,939,453	296,207	13,015,362	71.8
1914	149,342	6,519,636	255,524	9,350,245	58.4
1915	207,936	11,919,060	388,644	17,450,385	53.5
1916	346,370	34,494,480	589,738	50,281,692	58.7
1917	356,462	53,980,132	634,021	83,731,724	56.2
1918	448,204	72,897,550	750,868	115,433,943	59.7
1919	218,259	31,067,123	419,638	53,730,964	52.0
1920	340,743	50,169,570	612,808	77,519,367	55.6
1921	161,198	14,581,323	248,627	21,697,785	64.8
1922	206,966	14,148,302	423,280	28,259,004	48.9
1923	317,470	28,515,265	579,817	49,877,231	54.8
1924	260,623	24,618,060	497,244	43,249,948	52.4
1925	300,277	29,143,978	616,222	53,048,100	48.7
1926	376,301	35,975,381	689,258	61,368,407	54.6
1927	344,032	32,137,339	646,749	55,163,574	53.2
1928	384,203	35,129,555	794,695	66,578,039	48.3
1929	428,629	42,361,076	829,324	75,506,078	51.7
1930	340,475	29,627,740	650,240	51,900,220	52.4
1931	173,565	15,067,302	398,295	30,764,549	43.6
1932	96,247	6,733,066	218,646	14,003,672	44.0
1933	175,172	13,756,984	421,423	28,653,794	41.6
1934	165,650	16,375,553	428,798	34,634,957	38.6
1935	211,947	21,811,210	592,176	48,891,592	35.8
1936	336,889	30,465,371	853,531	69,135,074	39.5
1937	428,582	42,548,365	970,651	86,140,492	44.2
1938	188,697	19,624,173	464,112	42,459,513	40.7
1939	288,078	29,609,712	841,162	76,156,588	34.2
1940	457,298	56,983,213	1,154,161	128,127,810	39.6

[1] Ferro-alloys were first reported separately from pig iron by United States Geological Survey in 1911; data separated by States beginning in 1912.

[2] Calculated by weight.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

tion meanwhile increased 330 percent, as is shown in the following table. Pennsylvania, meanwhile, increased her ferro-alloy production by 120 percent. Yet the growth of the iron and steel industry in the Central States and on the Pacific Coast supplied the greater part of the increase, so that Pennsylvania's fraction of the national production fell from 62 percent in 1912 to 40 percent in 1940. The fact that steel tonnage has not kept pace with production of ferro-alloys is due to a decrease in the proportion of imports of these products and an increased weight of alloying elements used per ton of steel.

The production data also show the influence of war and of depression. Pennsylvania's high production of 1918, last year of the First World War, was almost as great as that in 1940, when the country was busily arming Britain and was herself severely threatened by war. The effect of the short depression of 1921 is discernible in the table, and the shocking "low" of the 1930's is strikingly evident. In 1932 the national production of ferro-alloys was less than that of 1901.

Through the courtesy of the American Iron and Steel Institute we are able to present the following tables showing the production of pig iron and ferro-alloys and of steel ingots and castings in Pennsylvania for a series of years. These figures are all stated in net tons. Special attention is drawn to the remarkable increase in the production of electric steel during the past few years.

Some differences exist between the following figures and similar ones issued by Federal agencies. These are largely due to differing sources and methods of collection.

TABLE 64. PRODUCTION OF PIG IRON AND FERRO-ALLOYS IN PENNSYLVANIA

(Net tons)

Year	*Pig iron and ferro-alloys*	*Pig iron*	*Ferro-alloys*
1872	1,401,497	....	....
1873	1,389,573	....	....
1874	1,213,133	....	....
1875	960,884	....	....
1876	1,009,613	....	....
1877	1,153,356	....	....
1878	1,342,633	....	....
1879	1,607,763	....	....
1880	2,083,121	....	....
1881	2,190,786	....	....
1882	2,449,256	....	....
1883	2,638,891	....	....
1884	2,385,402	....	....
1885	2,245,496	....	....
1886	3,293,289	....	....
1887	3,684,618	....	....
1888	3,589,186	....	....
1889	4,181,242	....	....
1890	4,945,169	....	....
1891	4,426,673	....	....
1892	4,697,062	....	....
1893	4,080,185	....	....
1894	3,774,570	....	....
1895	5,265,303	....	....
1896	4,507,066	....	....
1897	5,187,430	....	....
1898	6,202,372	....	....
1899	7,345,943	....	....
1900	7,129,847	....	....
1901	8,224,448	....	....
1902	9,091,936	....	....
1903	9,196,880	....	....
1904	8,561,640	....	....
1905	11,848,622	....	....
1906	12,597,613	....	....
1907	12,710,375	....	....
1908	7,825,654	....	....
1909	12,229,083	....	....
1910	12,625,002	....	....
1911	10,983,922	....	....
1912	14,058,386	....	....
1913	14,509,528	....	....
1914	10,901,373	....	....
1915	14,325,548	....	....
1916	18,487,038	....	....
1917	17,404,495	....	....
1918	17,022,064	....	....
1919	13,749,775	....	....
1920	15,661,110	....	....
1921	7,003,098	....	....
1922	....	10,677,565	220,038
1923	....	16,209,657	371,517
1924	....	12,112,999	284,257
1925	....	13,708,549	317,754
1926	....	14,819,917	398,710
1927	....	12,842,432	406,719
1928	....	13,498,694	414,621
1929	....	15,697,937	489,704
1930	....	11,163,732	377,740
1931	....	5,642,193	219,018
1932	....	2,355,562	95,417
1933	....	4,176,300	183,454
1934	....	4,753,914	184,549
1935	....	6,137,367	246,341
1936	....	10,195,220	370,119
1937	....	12,735,786	489,793
1938	....	5,416,285	184,687
1939	....	9,809,487	309,543
1940	....	14,287,826	515,263
1941	....	16,894,775	620,305
1942	....	18,065,289	627,368

SOURCE: American Iron and Steel Institute.

TABLE 65. PRODUCTION OF STEEL INGOTS AND CASTINGS IN PENNSYLVANIA
(Net tons)

Year	*Open Hearth*	*Bessemer*	*Electric*	*Crucible*[2]	*Total*
1901	4,026,134	4,808,652	(1)	83,776	8,918,562
1902	4,900,408	4,714,445	....	99,530	9,714,383
1903	4,975,858	4,378,568	....	90,116	9,444,542
1904	4,823,278	3,880,408	....	71,622	8,775,308
1905	7,248,437	5,030,418	....	86,419	12,365,274
1906	8,644,398	5,407,052	....	101,679	14,153,129
1907	8,812,555	4,874,062	....	99,400	13,786,017
1908	5,960,896	2,359,148		41,724	8,361,768
1909	10,528,321	3,187,074	71,568	(3)	13,786,963
1910	11,372,274	3,332,840	87,330	....	14,792,444
1911	10,746,304	2,619,471	63,611	....	13,429,386
1912	13,897,082	3,536,879	75,843	....	17,509,804
1913	14,024,894	3,309,396	86,519	....	17,420,809
1914	11,036,523	2,256,269	62,957	....	13,355,749
1915	14,834,840	2,808,112	89,525	....	17,732,477
1916	17,953,881	3,857,463	137,499	....	21,948,843
1917	18,238,194	3,961,545	198,193	....	22,397,932
1918	17,442,993	3,675,774	236,686	....	21,355,453
1919	14,215,165	3,193,570	149,449	....	17,558,184
1920	15,886,614	3,672,506	190,231	....	19,749,351
1921	7,177,008	1,865,311	52,259	....	9,094,578
1922	12,973,869	2,771,951	89,332	....	15,835,152
1923	16,159,569	3,489,741	142,068	....	19,791,378
1924	13,712,959	2,476,172	120,522	....	16,309,653
1925	15,704,360	2,636,739	168,293	....	18,509,392
1926	17,497,600	2,711,205	161,344	....	20,370,149
1927	15,353,135	2,361,501	142,026	....	17,856,662
1928	17,093,119	2,568,255	179,027	....	19,840,401
1929	19,605,384	2,718,789	225,894	....	22,550,067
1930	13,986,756	1,940,450	159,617	....	16,086,823
1931	8,270,182	881,179	102,761	....	9,254,122
1932	3,927,255	261,201	60,477	....	4,248,933
1933	6,421,825	670,513	105,611	....	7,197,949
1934	7,255,237	639,315	108,430	....	8,002,982
1935	8,792,795	856,131	163,091	....	9,812.017
1936	14,463,571	1,067,328	218,263	....	15,749,162
1937	16,309,104	930,093	249,787	....	17,488,984
1938	7,920,816	389,827	151,186	7	8,461,836
1939	13,622,272	1,109,081	264,190	931	14,996,474
1940	18,469,170	1,366,017	441.327	1,024	20,277,538
1941	23,007,147	1,966,779	799.387	2,313	25,775,626
1942	23,562,866	1,997,547	1,054,745	2,010	26,617,168

[1] Electric steel not separately reported prior to 1909.
[2] Figures prior to 1909 represent "Crucible and all other steel" (not shown in first two columns).
[3] Crucible and electric steel were combined in years 1909 to 1937, inclusive.
SOURCE: American Iron and Steel Institute.

CHROMITE

The mineral chromite is the most important source of chromium, a metal now in great demand for many uses, particularly for stainless steels and plating. An area of basic rocks extending from southeastern Pennsylvania into Maryland has been known to contain this mineral for many years. From 1828 to about 1860 this district was practically the only source of supply for the world. The Wood Mine, located in Pennsylvania, was at one time the largest source of chromium in the world. It was worked from 1827 to 1882, except during 1868 to 1873 when it was flooded.[1] No accurate record of production has been known. After the Civil War this mine, which before 1868 was reported to have produced as much as 400 to 500 tons monthly, reduced its output to 400 to 500 tons per year. Total output has been estimated to have been about 95,000 tons of chrome ore.[2] In addition Maryland is estimated to have produced over 100,000 tons.[3] It is probable that the region as a whole has produced something in excess to 200,000 tons of high grade ore.

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[1] Knopf, E. B., Chrome Ores of Southeastern Pennsylvania and Maryland; U. S. Geol. Survey Bull. 725.

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[2] Second Geological Survey of Pennsylvania. The Geology of Lancaster County, Preston, Frazer, 1880.

[3] Mineral Resources of the United States, 1892.

COPPER

A total of several million pounds of copper has been mined in Pennsylvania. In recent years, however, production has been limited to a single source and hence detailed figures are not available for publication. Earlier figures of official record are given in the following table. Since 1930 the United States Bureau of Mines has published no separate copper production statistics for Pennsylvania.

TABLE 66. COPPER PRODUCTION IN PENNSYLVANIA

Year	*Pounds*	*Value*
1910	740,626	$94,060
1911	661,621	82,703
1912[1]	....	....
1913	503,792	78,088
1914[1]	....	....
1915[1]	....	....
1916	625,000	153,750
1917	459,200	125,362
1918	779,393	192,510
1919[1]	..	
1920	405,092	74,537
1921	313,302	40,416
1922	1,229,926	166,040
1923	1,703,480	250,411
1924	1,114,694	146,025
1925	1,035,824	147,087
1926	1,018,536	142,595
1927	1,735,800	227,390
1928	4,977,885	716,815
1929	3,454,170	607,934
1930	2,859,675	371,758

[1] Included under miscellaneous.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

LEAD AND ZINC

Neither lead nor zinc is produced in Pennsylvania in commercial quantities at present. There have been periods in the past during which the State was an important producer of these ores. Unfortunately, accurate production records have not been preserved and total output is a matter of conjecture.

Lead and zinc minerals have been found in many localities. They are commonly associated with limestones. Most occurrences are of scientific interest only. The first mining operations of record were carried on in the southern end of Sinking Valley in 1778. Interest was in the production of lead. The metal was used for bullets by the Continental Army. A sale of 1,000 pounds to the State at $6.00 per pound in depreciated currency is reported.[1]

Zinc has been produced in greater tonnage than lead. The Bamford mine in Lancaster County is reported to have produced as follows:

TABLE 67. ZINC PRODUCTION

Year	*Net tons*
1873	20
1874	86
1875	164
1876	87

By far the greatest production has been supplied by the Friedensville ores in Lehigh County. It is estimated that 50,000 tons of spelter and 90,000 tons of zinc oxide, valued at approximately $20,000,000 have been produced from these ores.[1] Operations were halted by uncontrollable flows of water. Substantial tonnages of unmined ore are believed to exist.

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[1] Lead and Zinc Ores of Pennsylvania. By Benjamin LeRoy Miller, Pennsylvania Geological Survey. Fourth Series. Bulletin M5.

GOLD AND SILVER

The occurrence of gold and silver has been reported occasionally in widely scattered areas in Pennsylvania. Production on a commercial basis did not become significant until 1922. Since that year production has been continuous on a small scale. This output of the precious metals is not the result of mining operations carried on directly for that purpose but is derived as a by-product of iron mining. Certain magnetites contain pyrite with which copper, gold, silver, and cobalt are associated. The removal and concentration of this material permits the economic recovery of these metals. Unless further discoveries are made, which is not probable, production will coincide with activity in the mining of these iron ores and eventually will decline as the mine approaches exhaustion.

NICKEL

The nickel ores found near Gap had been worked as early as 1852. The mine had been worked at an earlier date for copper. It has not been worked since January, 1883.[1] Total production of metal during its active life is estimated at about 4,000,000 pounds. However, at one time this output represented about one-sixth of the total for the world.[2]

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[1] Mineral Resources of the United States, 1883.

[2] Report of the Royal Ontario Nickel Commission, 1917.

TABLE 68. GOLD AND SILVER PRODUCED IN PENNSYLVANIA

	Gold		Silver	
Year	*Troy ounces*	*Value*	*Troy ounces*	*Value*
1922	116	$2,400	2,141	$2,141
1923	157	3,246	3,005	2,464
1924	214	4,424	2,810	1,883
1925	237	4,900	3,120	2,165
1926	22	450	544	339
1927	300	6,201	2,000	1,134
1928	992	20,506	7,905	4,624
1929	836	17,282	5,972	3,183
1930	630	13,023	5,762	2,218
1931	252	5,200	2,600	754
1932	80	1,660	830	234
1933	209	5,342	2,300	805
1934	623	21,774	6,230	4,027
1935	745	26,075	5,843	4,200
1936	890	31,150	8,118	6,287
1937	1,348	47,180	9,497	7,346
1938	1,422	49,770	9.360	6,051
1939	1,815	63,525	13,558	9,203
1940	1,840	64,400	13,064	9,290
1941	2,422	84,770	15,016	10,678
1942	2,499	87,465	15,501	11,023

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

SMELTING AND MANUFACTURE OF NONFERROUS METALS

The data already presented show that Pennsylvania does not mine copper, lead, zinc or any of the other nonferrous metals in large quantities Nevertheless, the State is a leading manufacturer and fabricator of nonferrous metals and their products. This is due to the availability of skilled labor, superior fuels, and immediate markets.

The following table presents statistical information concerning the most significant branches of this group of industries. The fabrication of metallic aluminum products is also a large employer of Pennsylvania skilled labor.

Pennsylvania is the Nation's leading producer of primary slab zinc, derived directly from smelting zinc ores, although at the present time this State is not a producer of the ores themselves. The greatest single market for zinc is in the steel industry, which consumes enormous quantities in the manufacture of a wide variety of galvanized products. Sulphuric acid, most of which is produced as a byproduct from the smelting of zinc ores, is obtained in such quantities as to place Pennsylvania in the first rank in the United States.

TABLE 69. SELECTED NONFERROUS METAL PRODUCTS SMELTED OR MANUFACTURED IN PENNSYLVANIA

	Babbitt metal[1]		Brass and bronze products[2]		Copper—smelting and refining		Lead refined and recovered[3]		Zinc—refined and recovered	
Year	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*
1921	407	$2,297,300	6,489	$17,270,800	437	$2,909,000	106	$1,868,700	[4] 2,079	[4] $12,455,200
1922	158	1,953,300	4,847	22,594,200	279	3,053,700	84	1,381,200	[5] 3,118	[5] 25,964,300
1923	195	2,857,300	6,689	30,829,700	152	2,453,600	98	1,543,100	[5] 3,944	[5] 35,103,500
1924	352	3,469,000	8,173	27,253,900	499	3,546,600	104	1,595,900	[5] 3,770	[5] 32,360,600
1925	207	4,446,300	6,051	34,752,100	471	4,366,400	122	2,518,600	[5] 3,801	[5] 32,161,500
1926	724	9,797,000	6,221	28,882,700	278	4,320,300	124	1,655,700	[5] 4,043	[5] 35,259,200
1927	507	7,632,300	3,147	26,077,000	260	3,859,900	142	1,380,600	[5] 4,001	[5] 33,903,300
1928	621	6,198,700	5,886	28,243,700	653	5,474,900	..	....	4,220	33,936,300
1929	358	7,229,200	4,505	36,385,100	1,034	8,430,100	...	....	4,410	37,121,800
1930	249	5,931,300	4,075	24,084,600	941	7,607,200	..	....	3,925	25,454,200
1931	219	3,792,500	3,255	13,271,500	634	4,114,700	...	...	3,386	16,406,800
1932	275	1,541,500	2,974	9,151,600	527	3,652,400	...	..	2,700	10,048,400
1933	803	4,129,000	3,453	12,766,800	499	3,042,600	...	...	2,963	15,775,600
1934	682	5,810,500	3,898	15,507,000	435	2,843,500	...	..	3,650	17,275,900
1935	541	6,437,400	5,071	21,037,200	8	144,400	...		4,351	22,288,400
1936	858	8,260,100	5,245	26,874,100	4	48,200	.	.	4,702	27,912,800
1937	770	11,413,800	6,387	43,042,200	59	454,000	.		5,217	31,583,200
1938	1,242	10,285,600	5,141	26,425,900	66	437,000			4,689	19,861,900
1939	985	10,854,100	6,262	39,775,100	53	202,600		....	4,961	24,202,000
1940	877	11,482,300	7,899	49,428,400	45	231,900		..	5,395	34,055,900
1941	1,047	17,549,400	10,006	92,901,500	44	1,457,400		...	6,261	45,546,800

[1] Includes babbitt metal and solder, 1921 to 1927; beginning with 1928 this classification was defined as babbitt metal, white metal, type metal and solder.

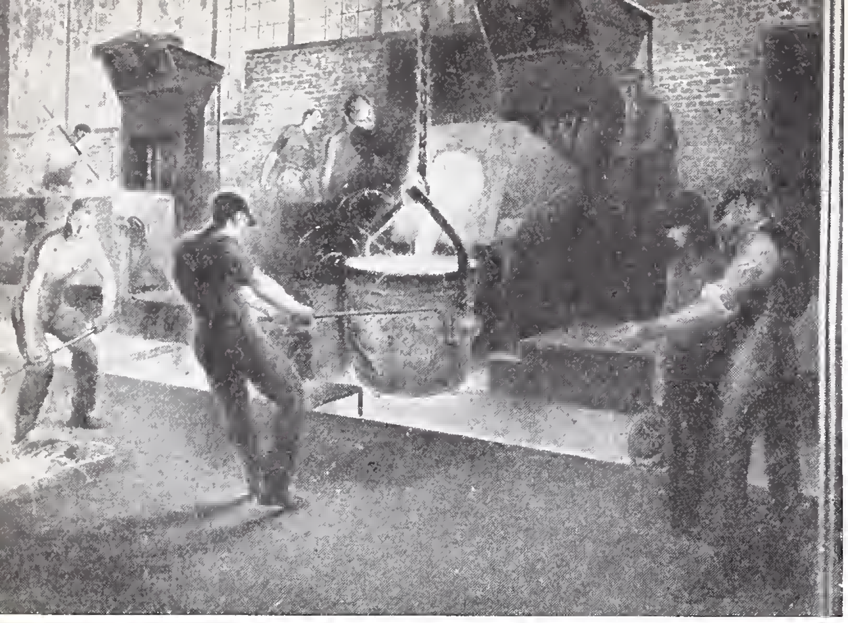
[2] Beginning with 1928 this classification was defined as brass, bronze and copper products.

[3] Not tabulated separately after 1927.

[4] Includes only miscellaneous zinc products.

[5] Includes spelter and miscellaneous zinc products.

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.



Induction Electric Steel Furnace
by Edmund M. Ashe

TABLE 70. PRIMARY SLAB ZINC PRODUCED IN PENNSYLVANIA AND THE UNITED STATES

(Net tons)

Year	*Pennsylvania*	*United States*	*Percentage of United States total*
1906	8,659	224,770	3.9
1907	11,266	249,860	4.5
1908	6,818	210,424	3.2
1909	15,222	255,760	6.0
1910	16,459	269,184	6.1
1911	15,337	286,526	5.4
1912	18,254	338,806	5.4
1913	26,934	346,676	7.8
1914	28,095	353,049	8.0
1915	44,167	489,519	9.0
1916	76,545	668,343	11.5
1917	86,995	669,573	13.0
1918	77,342	517,927	14.9
1919	67,521	465,743	14.5
1920	74,234	463,377	16.0
1921	36,378	200,500	18.1
1922	57,319	354,277	16.2
1923	82,003	510,434	16.1
1924	83,016	517,339	16.0
1925	99,899	572,946	17.4
1926	100,538	618,422	16.3
1927	106,099	592,516	17.9
1928	108,802	602,581	18.1
1929	108,167	625,447	17.3
1930	101,916	498,045	20.5
1931	65,445	291,996	22.4
1932	55,536	207,148	26.8
1933	62,583	307,182	20.4
1934	100,728	363,590	27.7
1935	119,452	420.634	28.4
1936	150,425	492,132	30.6
1937	175,275	556,904	31.5
1938	139,897	446,341	31.3
1939	155.598	507,236	30.7
1940	175,352	675,275	26.0
1941	222,486	822,020	27.1

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

TABLE 71. SULPHURIC ACID (60° BAUME) PRODUCED AS A BYPRODUCT IN THE SMELTING OF ZINC ORES IN PENNSYLVANIA

Year	*Net tons*	*Value*
1917	274,932	$4,407,588
1918	(1)	(1)
1919	(1)	(1)
1920	[2] 101,755	1,599,917
1921	98,766	1,271,000
1922	(1)	(1)
1923	(1)	(1)
1924	118,452	1,072,000
1925	141,818	1,224,000
1926	152,513	1,447,000
1927	159,112	1,553,000
1928	128,802	1,273,852
1929	141,634	1,363,935
1930	141,506	1,362,703
1931	(1)	(1)
1932	93,834	713,138
1933	113,596	856,514
1934	161,201	1,273,488
1935	195,324	1,654,394
1936	233,431	2,075,202
1937	263,341	2,456,972
1938	221,563	2,018,439
1939	254,758	2,295,370
1940	299,751	2,739,724

[1] Not tabulated separately for Pennsylvania.

[2] Includes several thousand tons of stronger acid not converted to 60° Baume.

SOURCE: *Mineral Resources of the United States* and *Minerals Yearbook.*

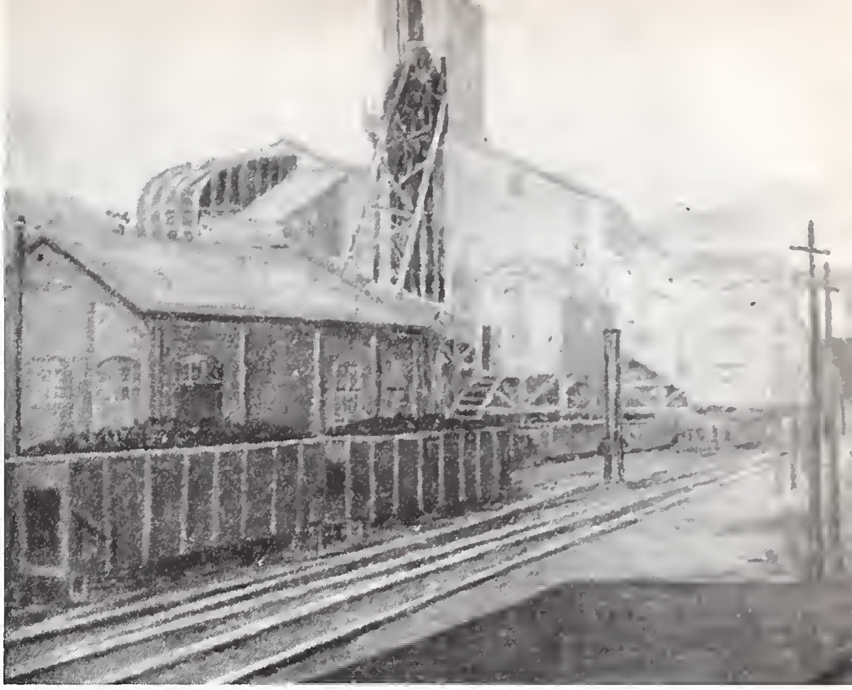
MINERALS AND MANUFACTURING

A twenty-year record of employment and value of production in each of several major groups of mineral industries is shown in the first of the two accompanying tables. The three groups of clay, glass, and stone products, metals and metal products, and mine and quarry products are the complete groups of industries as tabulated by the Department of Internal Affairs.

Chemicals and allied products shown in this table represent a selected list of such products, as follows: Ammonia; benzols; chemicals; gasoline; naphtha and naphthalene; oil—fuel; oil—kerosene; oils and greases—lubricating; oils—miscellaneous; sulphuric, nitric and miscellaneous acids; tar and tar products.

Miscellaneous products in this table represent a selected list of such products, as follows: Asbestos products; coke—beehive; coke—by-product; fuel—manufactured; magnesia products.

In the second table, more detailed information is presented, for the single year 1940, for each industry in the foregoing groups. To give a broader picture of the role of minerals in the manufacturing activities of Pennsylvania, data are included not only for employment and value of products, but also for capital investment, primary horsepower, wages and salaries, and value added by manufacture. Figures of this kind are of basic importance in any study of the economic development of the State and the estimation of possible future trends.



Bituminous Coal Tipple
by Godfrey F. Biehl

TABLE 72. MINERAL PRODUCTS MANUFACTURED OR MINED IN PENNSYLVANIA CLASSIFIED BY GROUPS OF INDUSTRIES

	Chemicals and allied products		*Clay, glass and stone products*		*Metals and metal products*		*Mine and quarry products*		*Miscellaneous products*	
Year	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*	*Employes*	*Value of products*
1923 . .	20,550	$254,134,000	63,350	$253,633,900	493,907	$4,054,745,400	367,293	$984,544,300	15,260	$164,290,100
1924 . .	19,937	216,573,300	60,303	239,026,400	452,928	3,255,559,500	342,237	795,637,500	14,008	97,312,200
1925 . .	20,215	260,523,200	63,662	257,396,900	453,237	3,401,812,600	332,097	648,379,300	13,771	107,607,800
1926 . .	21,540	276,598,800	62,447	259,303.200	468,999	3,353,529,300	339,073	824,393,400	12,157	103,192,200
1927 . .	20,252	252,975,100	59,774	233,454,300	436,127	2,947,123,200	338,333	734,317,200	9,026	72,779,600
1928 . .	20,137	296,951,000	58,235	229,217,900	432,791	3,024,934,200	311,160	670,532,000	8,201	69,018,700
1929 . .	21,820	321,533,800	58,513	236,225,300	466,920	3,569,277,700	303,083	691,314,900	8,983	78,380,100
1930 . .	21,937	296,218,100	52,271	188,089,500	415,780	2,701,954,800	300,328	605,336,200	7,778	60,746,300
1931 . .	22,843	236,113,300	43,343	126,518,800	323,996	1,546,978,800	265,170	466,216,100	5,705	36,517,000
1932 . .	19,220	207,289,800	35,349	80,907,400	245,410	802,472,300	223.821	330,629,700	4,333	20,844,900
1933 . .	22,097	208,741,200	39,170	92,949,900	280,508	1,048,749,000	223,644	326,036,000	6,244	29,219,100
1934 . .	25,620	263,421,100	44,269	117,182,600	324,123	1,347,137,500	236,046	420,015,500	7,028	33,186,300
1935 . .	24,593	272,903,200	45,500	137,997,800	349,451	1,654,008,400	229,910	396,533,800	6,702	40,070,000
1936 . .	25,670	319,719,500	49,077	173,194,200	416,151	2,440,137,800	233,398	457,630,500	8,057	62,919,700
1937 . .	26,007	364,998,300	52,314	199,561,600	475,589	3,058,279,700	230,307	446,197,300	8,694	65,861,100
1938 . .	22,488	293,017,100	43,519	135,972,200	368,767	1,721,644,700	209,895	351,641,000	6,743	35,207,500
1939 . .	23,832	329,409,200	47,895	178,145,100	414,112	2,128,209,800	201,321	382,520,900	8,054	55,435,400
1940 . .	20,476	364,680,600	52,938	206,608,300	489,298	2,944,848,400	202,539	452,753,600	10,210	75,776,700
1941 . .	23,010	474,602,100	62,064	283,014,800	637,929	4,617,188,200	200,559	535,038,700	11,609	99,665,700
1942 . .	26,520	413,345,100	63,210	301,051,100	720,959	6,143,211,800	208,630	677,444,000	11,672	100,107,700

SOURCE: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

TABLE 73. MINERAL PRODUCTS MANUFACTURED OR MINED IN PENNSYLVANIA, BY INDUSTRIES, 1940

Industry	*No. of establishments*	*Capital invested*	*Primary horsepower*	*Wage earners*	*Wages*	*Salaried persons*	*Salaries*	*Value of products*	*Value added by manufacture*
CHEMICALS AND ALLIED PRODUCTS									
Ammonia	4	$138,900	335	31	$36,300	8	$15,600	$4,894,800	$2,374,500
Benzols	...	....				.	.	2,050,800	644,800
Chemicals	109	30,619,000	60,189	4,265	6,004,000	1,512	3,771,800	63,190,800	33,744,900
Gasoline	40	113,150,500	132,083	4,904	10,565,100	1,182	3,285,200	109,305,500	20,682,600
Naphtha and naphthalene	..	....					...	2,614,400	1,063,000
Oil—fuel	1	24,201,000	17,413	726	1,672,600	128	291,400	59,128,100	11,421,400
Oil—kerosene	...	....	...	.	..	.	...	11,790,300	2,194,100
Oils and greases—lubricating	50	24,899,400	29,103	2,956	4,008,800	937	2,552,400	54,460,400	15,122,400
Oils—miscellaneous	26	9,030,400	7,087	1,262	1,796,100	493	1,418,100	22,108,800	7,082,800
Sulphuric, nitric and misecellaneous acids	7	4,429,700	7,269	786	1,329,800	132	341,800	15,904,400	8,187,800
Tar and tar products	11	3,969,300	6,742	955	1,499,000	199	545,200	19,232,300	8,140,700
CLAY, GLASS AND STONE PRODUCTS									
Brick—building	61	7,965,600	23,119	2,625	2,631,600	223	469,300	6,235,000	4,215,900
Brick—ganister	12	6,779,300	11,177	2,659	2,868,900	162	349,600	8,585,300	5,317,300
Brick—paving	1	38,000	157	23	14,500	1	2,600	246,500	180,000
Cement	25	47,344,600	264,076	5,731	7,897,200	1,189	3,501,600	35,688,500	20,820,700
Concrete products	200	5,603,300	7,638	1,433	1,325,900	290	520,600	5,876,600	3,169,400
Crucibles	3	619,700	671	187	235,100	54	235,000	1,349,600	974,600
Emery and other abrasive wheels	9	2,451,600	3,633	691	935,500	244	728,600	4,675,300	3,262,300
Glass—bottles and jars	17	13,536,700	22,947	4,661	6,707,700	447	1,113,800	29,180,100	15,804,800
Glass—cut	4	110,900	49	70	60,900	8	12,000	283,500	82,100
Glass—decorative	23	270,200	31	99	121,000	42	73,700	476,300	299,500
Glass—plate	6	13,471,500	51,216	4,146	5,153,000	450	968,600	21,497,700	11,069,600
Glass—tableware	9	4,008,800	6,455	2,264	2,450,100	184	406,600	6,750,600	4,565,200
Glass—window	4	9,590,800	3,341	1,858	3,148,300	86	198,100	7,030,100	4,839,900
Glass—miscellaneous products	39	9,138,400	11,758	4,721	5,559,900	557	1,241,200	23,259,000	17,122,100
Lamps, chimneys and reflectors	9	2,621,600	3,441	1,775	1,692,400	232	602,900	4,749,000	3,159,700
Lime	32	7,257,100	23,405	1,535	1,714,900	213	419,600	5,514,100	3,660,500
Mirrors	23	697,500	899	431	408,600	82	159,700	1,596,400	784,100
Paving materials—other than brick	29	1,827,300	5,774	299	255,500	71	153,300	2,402,200	992,100
Pottery and chinaware	16	5,236,800	3,282	2,875	3,475,400	261	763,700	8,341,800	6,365,600
Terra cotta and fire clay products.	76	26,176,700	42,660	7,992	9,027,900	555	1,420,400	25,930,400	17,066,500
Wall plaster	6	1,267,100	4,791	164	249,600	33	69,500	1,441,800	470,400
Unclassified clay, glass and stone products	30	3,326,900	4,679	1,126	1,240,100	189	554,900	5,498,500	3,250,500

Metals and Metal Products									
Agricultural implements and machinery	13	3,259,000	3,706	927	1,162,000	268	659,700	6,316,600	3,308,200
Aluminum—cooking utensils	3	1,691,300	6,433	1,765	2,768,800	587	1,129,300	12,349,800	7,779,200
Aluminum—miscellaneous products	14	10,462,600	31,548	5,105	8,297,200	769	1,846,000	34,579,000	20,064,100
Automobile and truck bodies—metal	12	15,429,700	27,558	6,874	11,493,000	759	2,294,100	42,996,900	20,081,300
Automobile parts	25	10,240,100	21,782	4,043	5,915,100	571	1,501,600	20,666,700	10,426,400
Axes and edge tools	5	1,315,700	2,821	354	440,900	62	156,800	1,393,600	783,800
Axles	2	2,256,300	3,191	347	552,700	17	44,600	4,504,400	1,928,000
Babbitt metal, white metal, type metal and solder	24	2,246,200	2,474	707	836,200	170	434,700	11,482,300	3,366,500
Bars—iron and steel	21	188,436,900	529,233	29,853	46,052,800	2,955	8,324,800	180,563,000	81,258,200
Beds and bed springs	10	260,200	371	195	190,600	25	75,300	1,517,300	693,500
Billets, blooms and slabs	3	76,505,300	224,788	10,121	15,464,700	1,237	3,567,100	112,631,400	39,796,900
Boilers, tanks, stacks and drums	77	18,468,100	42,858	5,351	7,068,300	1,110	2,677,000	32,410,500	15,921,600
Bolts, nuts, washers and rivets	22	27,474,600	75,163	6,742	8,656,800	963	2,537,700	28,236,700	15,254,600
Brass, bronze and copper products	120	19,739,400	37,701	6,877	8,402,900	1,022	3,006,700	49,428,400	20,501,400
Cars and parts—railroad and electric railway	19	37,638,600	82,321	9,212	12,403,900	1,059	2,592,900	106,971,300	37,913,700
Castings—iron	124	12,194,800	28,619	6,471	7,856,000	700	1,783,600	34,145,900	17,085,400
Castings—malleable iron	9	5,098,800	9,381	2,438	2,855,200	261	564,600	5,815,500	3,521,500
Castings—steel	30	34,244,400	75,816	9,823	13,292,500	1,180	3,537,700	46,407,000	29,369,300
Chains	11	4,400,100	9,408	1,732	2,537,700	282	540,800	12,083,700	7,426,300
Copper—smelting and refining	3	120,300	67	29	32,300	16	37,500	231,900	65,300
Cornices, ceilings, ventilators, etc.	39	3,602,700	3,949	1,389	1,536,100	332	614,200	7,847,100	3,612,700
Cutlery	6	669,800	437	334	335,300	22	34,200	640,400	397,000
Electrical machinery, apparatus and supplies	119	115,116,900	232,361	33,946	56,552,300	10,322	24,993,200	262,286,100	155,109,700
Electroplating	56	1,359,000	4,333	939	831,000	159	281,800	3,136,800	1,699,200
Elevators and hoists	30	3,368,300	2,987	980	1,420,700	341	708,700	6,717,100	3,725,400
Ferroalloys—unclassified	9	3,755,000	12,851	1,624	2,213,400	312	988,500	23,050,100	11,670,600
Files	3	1,534,200	2,145	437	610,100	31	106,500	2,472,600	1,832,100
Fire escapes	5	66,000	80	23	23,300	6	12,600	79,900	45,000
Fixtures—gas and electric	18	858,900	577	672	440,700	112	258,800	3,348,800	1,836,900
Forgings—iron and steel	30	22,494,800	61,904	5,353	8,394,200	664	2,318,700	51,525,300	28,609,100
Furniture—metal	22	2,680,900	2,256	1,563	1,671,000	250	570,800	8,045,500	4,003,200
Galvanizing and other coating	6	420,800	857	521	619,900	60	502,500	3,216,000	1,693,500
Gas and gasoline engines	4	3,786,900	4,351	1,665	2,347,500	272	527,900	7,529,200	4,084,300
Gold and silver leaf and foil	6	654,900	170	166	107,100	21	57,300	508,400	190,800
Gold, silver and platinum—reducing and refining	4	182,100	331	142	122,500	44	70,900	902,300	211,000
Hardware and specialties	134	22,991,300	28,331	8,373	8,895,500	1,576	3,979,400	40,133,300	23,133,300
Hoops, bands and cotton ties	8	23,225,800	92,735	5,200	7,378,300	489	1,438,700	47,680,800	16,830,600

TABLE 73. MINERAL PRODUCTS MANUFACTURED OR MINED IN PENNSYLVANIA, BY INDUSTRIES, 1940—Continued

Industry	*No. of establishments*	*Capital invested*	*Primary horsepower*	*Wage earners*	*Wages*	*Salaried persons*	*Salaries*	*Value of products*	*Value added by manufacture*
METALS AND METAL PRODUCTS—Contd.									
Ingots—iron and steel	1	$3,227,000	700	464	$816,200	64	$231,100	$25,032,100	$8,952,200
Instruments — professional and scientific	51	9,718,300	4,626	3,886	5,485,200	1,376	3,760,600	22,883,100	15,141,800
Iron—pig	7	46,933,400	168,826	2,401	3,654,100	255	848,300	58,787,300	14,426,400
Jewelry	70	1,364,900	391	408	478,400	186	349,400	2,242,800	1,262,100
Locomotives	4	43,035,700	78,471	3,449	5,574,200	990	2,524,700	18,758,700	8,596,100
Machine repair shops	224	8,357,100	14,096	2,306	2,892,600	584	1,292,700	10,935,300	7,006,600
Machine tools	75	7,332,500	11,018	3,873	6,164,100	767	1,838,600	24,559,400	16,670,300
Machinery and parts	301	161,769,200	274,247	43,622	68,109,100	9,928	24,541,400	207,961,400	123,831,300
Manganese—ferro	2	3,269,800	8,051	607	742,000	44	124,800	28,150,100	11,636,900
Meters	10	3,795,300	4,234	1,972	2,569,300	494	1,112,700	12,051,100	5,917,700
Motor vehicles	8	18,143,900	22,939	7,348	11,012,500	1,604	3,316,800	82,259,700	21,120,800
Nails and spikes	1	266,200	384	78	83,300	8	18,300	4,910,500	2,199,600
Needles, pins, hooks and eyes	7	5,655,700	3,515	3,871	5,109,500	1,414	2,850,600	23,761,500	18,403,100
Oil well supplies	29	7,266,200	20,389	1,751	2,470,100	386	995,900	10,924,200	6,074,800
Ornamental iron and steel	89	1,760,800	3,312	1,140	1,370,400	282	485,800	5,143,400	2,634,400
Pens and metal pencils	1	59,000	20	24	19,800	10	14,300	70,700	50,100
Pipes and tubing	32	144,719,600	476,875	29,734	52,103,800	3,615	10,020,400	184,589,200	74,681,200
Plates—iron and steel	6	103,195,100	148,419	14,822	22,912,100	1,314	3,585,700	94,962,500	33,862,900
Plumbers' supplies and steam fittings	49	11,268,100	18,010	5,660	6,742,800	708	1,573,500	20,124,600	11,982,900
Pulleys, hangings and bearings	18	8,029,900	14,466	3,377	5,850,100	837	2,027,300	24,535,900	17,755,900
Pumps and valves	28	8,702,500	9,529	1,977	2,628,000	631	1,443,800	8,611,100	5,158,700
Radiators	8	3,286,700	4,873	1,336	1,540,800	203	371,000	4,635,800	2,454,000
Radios and parts	9	4,639,300	5,557	6,373	6,144,500	1,239	2,332,100	41,730,400	14,533,500
Railroad supplies	22	74,759,500	93,561	9,412	8,329,300	2,135	5,451,800	72,546,700	34,360,300
Rails—iron and steel	1	14,830,800	37,085	3,767	6,089,500	318	905,800	18,909,000	6,484,800
Refrigerators—electric	6	833,500	872	320	337,900	52	134,900	1,508,200	796,000
Safes, vaults and locks	1	3,639,800	3,461	574	909,600	95	273,900	4,330,700	2,919,800
Saws	11	7,860,900	7,381	2,264	3,176,000	440	883,400	4,456,900	2,801,100
Scales	5	132,600	128	95	107,200	27	37,800	280,100	188,500
Shafting—cold rolled, drawn and turned	2	609,800	4,332	269	393,200	23	57,100	4,511,900	1,923,400
Shapes—structural	10	32,754,800	180,241	7,108	11,850,500	563	1,685,000	69,719,000	26,136,800
Shapes—other than structural	41	38,482,900	77,991	10,973	18,155,600	1,394	4,279,100	89,254,900	46,358,300
Sheet metal products, not elsewhere classified	78	5,368,400	5,331	1,823	2,108,600	428	992,100	10,940,000	5,198,000

Metals and Metal Products—Contd.									
Sheets—iron and steel	13	211,846,900	486,772	25,069	45,967,000	2,589	8,206,500	133,750,500	53,805,400
Shovels, scoops and spades	1	86,100	90	26	22,400	4	9,300	101,900	58,300
Silverware and plateware	1	13,300	19	15	16,500	7	9,900	53,000	35,000
Springs	24	3,478,100	8,723	1,578	2,129,200	257	684,800	10,534,100	5,391,100
Stationary engines—steam	4	2,688,100	1,988	276	381,500	85	258,000	4,228,600	2,561,400
Stoves, heaters and ranges	50	9,269,700	10,463	3,316	3,861,000	730	1,663,100	21,986,000	11,073,800
Structural iron and steel	46	28,211,600	67,662	7,786	11,399,700	1,205	3,152,200	68,474,200	31,290,700
Tin and terne plate	4	26,460,300	38,373	5,337	6,364,100	270	902,800	63,015,300	24,313,200
Tinners' and roofers' supplies	7	1,061,300	218	213	291,500	60	119,200	1,352,200	535,700
Typefounding	2	12,200	8	5	5,600	4	6,200	24,000	16,400
Typewriting machines	1	67,900	50	28	31,000	3	1,700	60,300	35,000
Ware—enameled	15	6,589,000	14,597	4,648	5,247,600	302	684,600	15,623,400	9,124,300
Ware—tin and stamped	33	14,324,700	8,431	3,053	3,234,500	496	1,171,400	24,343,700	7,430,100
Washing machines and wringers	1	874,000	3,200	491	573,200	80	172,100	2,142,900	1,227,700
Watches and clocks	2	1,463,200	924	1,459	1,856,000	333	695,000	5,134,200	2,583,700
Welding and brazing	41	760,500	2,448	673	803,100	128	280,400	3,301,100	1,746,300
Wire and wire products	68	22,694,300	87,652	8,791	13,072,400	923	2,295,100	80,850,500	37,620,700
Wire rods	...	...	...	...	...	...	...	22,277,200	10,245,300
Zinc—smelting and refining	7	20,353,200	44,861	4,863	7,331,700	532	1,758,500	34,055,900	12,619,200
Unclassified metal products	89	8,815,200	9,850	2,314	2,513,500	532	1,308,000	45,609,600	17,321,500
Mine and Quarry Products									
Clay	21	705,100	2,114	275	225,900	23	42,400	556,000	381,600
Coal—anthracite	139	274,204,900	684,816	76,957	97,151,800	4,188	9,262,100	192,539,500	...
Coal—bituminous	440	312,681,800	743,598	106,230	136,582,000	3,774	8,969,500	218,504,200	...
Coal—reclaimed from streams	25	423,400	2,844	268	255,200	21	48,900	851,000	...
Ganister rock	4	65,000	505	81	69,100	4	6,200	159,700	124,200
Marble and granite—cutting and polishing	187	3,389,500	6,494	735	758,200	336	556,000	4,212,500	2,439,200
Ore—iron	1	6,319,000	12,556	630	857,600	30	100,500	4,061,600	...
Sand and gravel	74	10,222,300	32,803	1,180	1,543,700	244	683,800	6,057,600	...
Sand—glass	8	1,412,200	5,417	308	383,800	33	98,100	1,732,000	1,276,800
Slate—roofing	15	1,388,300	8,327	1,012	983,300	60	133,700	1,370,000	1,122,800
Slate—miscellaneous	11	1,205,700	5,259	500	470,700	36	61,000	1,457,400	1,053,600
Stone—crushed	120	8,694,300	44,673	2,617	2,393,300	276	486,500	10,213,600	6,537,300
Stone—cut	22	468,100	2,232	169	151,900	39	49,100	435,200	308,600
Stone—miscellaneous	21	9,177,100	42,182	1,779	2,370,800	144	433,800	7,489,500	5,674,100
Unclassified mine and quarry products	27	4,636,900	12,965	496	549,400	94	259,900	3,113,800	1,632,500
Miscellaneous Products									
Asbestos products	11	5,172,000	14,513	2,788	3,472,200	552	1,285,900	12,956,200	7,478,700
Coke—beehive	16	3,401,500	5,399	1,131	803,100	37	49,000	7,636,300	2,226,500
Coke—by-product	7	81,947,600	117,994	4,577	6,970,200	474	1,289,200	51,647,300	13,289,600
Fuel—manufactured	1	769,000	1,521	89	108,400	10	38,900	508,000	266,500
Magnesia products	3	3,379,700	7,171	502	616,600	50	186,200	3,028,900	1,619,800

Source: Pennsylvania Department of Internal Affairs, Bureau of Statistics.

PART II

MINERAL RESOURCES

By

PENNSYLVANIA TOPOGRAPHIC AND GEOLOGIC SURVEY

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ORIGIN AND HISTORY OF PENNSYLVANIA'S MINERAL RESOURCES

PENNSYLVANIA'S mineral resources are not original constituents of the earth, but the result of events and conditions existing in the State's long geologic history. The sands and gravels may have washed down the valleys or formed by the disintegration of sandstones and conglomerates in recent centuries. The coal was formed about 200 million years ago. The limestones of Nittany Valley, Kittatinny Valley, and around Lancaster date back 400 million years or more. The quartzite at Chickies Rock is more than 500 million years old and some of the rocks in the Philadelphia region are much older.

The mineral resources of Pennsylvania are mainly useful beds of rock which were laid down in great continental seas, or in lakes or swamps. A few of them are igneous rocks that pushed their way up in molten form, and a very few are nonbedded deposits formed chemically by migrating water, especially in connection with igneous intrusions.

The oldest rocks are the pre-Cambrian, highly metamorphosed rocks of southeastern Pennsylvania. Some originally were sediments, now altered by intrusive igneous rocks, such as granites and related rocks, or by pressure and folding. These are useful mainly as building stones, but associated with them are iron ores, lead and zinc, chrome and nickel ores, copper, marble, graphite, feldspar, and other minerals or ores. Their history is complex and is not clear. When Cambrian time began, all of Pennsylvania was a sea; sand was being deposited in it, presumably off-shore from a land somewhere to the southeast of Pennsylvania. This sand, later changed to quartzite, is the source of building stone, mortar and silica sand, white clay and iron ore. Then the sea bottom that was to become Pennsylvania and the land to the southeast sank, resulting in the accumulation of thousands of feet of limestone and dolomite of Cambro-Ordovician age, from which are derived most of the rock used for lime, flux, and cement, for building stone and other limestone industries. About 400 million years ago, uplift at the southeast led to spreading a great sheet of mud over all of Pennsylvania, locally several thousand feet thick. This mud now compacted to shale is used for brick and tile and in the eastern area compression has converted it to slate.

At the end of Ordovician and beginning of Silurian time, uplift at the east, with rock folding to the northeast (Taconic Revolution), supplied material for a great thickness of sandstone that spread over all of Pennsylvania. This yields silica brick materials and building stone, and is responsible for much of our mountain scenery. Then followed during Silurian time, deposition of material that eventually became shale, sandstone, and limestone from which building stone, natural cement and brick and tile have been made. Two marine deposits deserve special mention. In the Clinton (Rosehill) epoch, vast quantities of water rich in iron washed old shores that stretched from Lake Ontario to Alabama. On the shores were sea shells. The water dissolved the shells and left iron in their place, giving to Pennsylvania and the other States the Clinton red hematite iron ores. In late Silurian (Salina) time, vast lagoons formed on the edge of the ocean. Oceanic water washed into them and evaporated, forming beds of salt that today underlie southern New York and much of northern and western Pennsylvania.

The Silurian ended and the Devonian began with the formation of limestones, the Tonoloway and Helderberg. They have minor value for many of the uses of limestone, but are not suitable for chemical lime or portland cement. Then conditions led to spreading over most of the State a thin bed of sandstone locally pure and white and suitable for making fine glass and for other purposes requiring a very pure silica sand. Another limestone followed and then for a long period the shore lines slowly migrated back and forth from east to west. Sand, clay, and gravel were deposited on the old land surface behind the shore; sand and clay or mud off shore for a short distance; then all mud farther out, and still farther out, say 100 miles, only black mud and lime. The sandy, close-to-shore deposits later became the State's oil and gas sands. The on-shore deposits were exposed to the air, and any material that might have distilled to oil and gas disintegrated and disappeared. Far off shore, the black mud and limey zone may have had plenty of oil- and gas-making material, but no porous sandstones or other rock to serve as a reservoir. As the shore migrated back and forth, these conditions moved also. Thus, the eastern oil and gas fields, as the Bradford field, are in the oldest rocks, and oil and gas occur in successively younger rocks westward. Thus, the First, Second, and Third sands of Venango County are 1,200 to 1,800 feet stratigraphically above the Third Bradford sand of the Bradford field.

Toward the end of Devonian time, the earth's crust again became restless, not in Pennsylvania, but within a short distance to the northeast when it was squeezed into folds (Caledonian Revolution) and doubtless formed mountains from which sand and gravel gradually spread across the State to form the mountain-making sandstones under the Pocono Plateau and in Second Mountain near Harrisburg, Terrace Mountain and others, and in western Pennsylvania, including the "Big Injun" oil and gas sand. In central and eastern Pennsylvania, these sandstones (Pocono) are used for building and structural purposes. Then followed the red shales and sandstones of the Mauch Chunk series, of minor value for brick, tile and similar products.

Then came the Coal Measures, the Pennsylvanian system. This again began with thick, massive sandstones, the Pottsville, which have furnished building stone, glass sand, and sand and stone for other purposes, and are mountain-makers. The Coal Measures are important as the source of coal and clay. The coal beds formed in great swamps, some of them spreading over tens of thousands of square miles and up to 400 miles across; in the anthracite area vegetation must have accumulated locally to several hundred feet deep. Conditions changed frequently as the Coal Measures consist of scores, even hundreds, of alternating beds of coal, clay, shale, sandstone, and limestone, each of which records a change of conditions. Widespread clays, which range from 6 inches to 30 feet thick, underlie practically all of the coal beds. Some of these clays are high in alumina, and of value for making fire brick and as a future source of aluminum. Widespread limestones in the Coal Measures (e.g. the Vanport) furnish flux stone, chemical lime, and cement.

The Coal Measuers were followed by crustal folding (Appalachian Revolution) that shortened Pennsylvania by many miles and raised the surface above sea level and for a time made eastern Pennsylvania a mass of mountains many thousands of feet in height. During millions of years thereafter, the State was worn down toward sea level.

During one interruption, in Upper Triassic time, the earth's crust did not contract but expanded, gradually letting down the area in eastern Pennsylvania now covered by Triassic deposits. At the same time molten trap rock welled up through the other rocks, sometimes to the surface, sometimes to spread out between the other rocks, which were lifted and baked. These rocks yield building stone, crushed stone, "black granite," and magnetic iron ore. Then, not long ago, Pennsylvania, having worn down essentially to a plane, was elevated, uplift centering in a north-south line across the middle of the State. As uplift proceeded, the rivers deepened their channels, the surface over the soft rocks wore down and widened out into broad valleys in the central part of the State, and the topography of today resulted. The recency of this uplift has resulted in narrow valleys in western Pennsylvania and where streams cross hard rocks in eastern Pennsylvania; valleys not highly suited to industrial establishments or cities, in many areas making the disposal of waste difficult and transportation circuitous. As compensation the rocks and mineral resources are better displayed in the banks of the rivers and valleys, thus inviting development, and our scenery is undoubtedly much more attractive than it would have been had the surface remained flat as in some States.

PENNSYLVANIA'S ROCKS AND MINERAL RESOURCES IN ORDER OF AGE

The mineral resources of Pennsylvania consist of: 1, sandstones, limestones, shales, and other rocks used as rocks or for the rock products they yield; 2, the associated beds of coal, clay, and iron ore, and deposits of petroleum and natural gas; and 3, iron ores and other nonbedded ores and deposits precipitated from solution associated with these rocks. There is here presented a table showing in outline the succession of rocks in their order, one above another, and of the mineral resources derived from them or associated with them. Some of these beds, such as the Pittsburgh coal bed, are uniform in character over large areas. More often the beds as laid down and as they occur today vary within wide limits from place to place just as the original deposits varied. So much do most of the beds vary that it is necessary, in describing or mapping them, to divide the thousands of feet of strata into belts, zones, or groups of rocks, each of approximately the same age and of the same general character. A group of rocks may consist of a dozen, a score, or a hundred individual layers, some thin, some thick, some widespread, some quite local. Thus we speak of the Hamilton formation or group, which may consist mainly of black shales or limestones in western Pennsylvania, of gray shales in central Pennsylvania, and of light brown sandstone in eastern Pennsylvania, all laid down at the same time but differing because of their differing distances from the shore line. At that time the material to make the sandstone was laid down close to shore, the gray shale within 40 to 50 miles from shore, while the black shale or limestone may have been laid down 100 miles or more offshore. These formations or groups of rock beds may be further gathered into what are called "series," and several series gathered into a major "system" of rocks. The following table lists the systems, series, and groups of rocks, indicates by abbreviations the characteristics of the rocks, and by abbreviations or words the mineral resources found in each of the rock groups.

PENNSYLVANIA'S ROCKS AND MINERAL RESOURCES IN ORDER OF AGE

Resources in capitals, important; beginning with capital, of intermediate value; all small letters. of minor value.

Abbreviations; ag-lime, agricultural lime; brk. brick or tile (clay or shale); bldg. building; cgl. conglomerate; cl. clay; crhd. crushed; dol. dolomite or dolomitic; lst. limestone; qtzite. quartzite; sd. sand; sh. shale; sl. slate; ss. sandstone; st. stone; W. Water supply large; (U) Upper; (M) Middle; (L) Lower.

System	*Series*	*Group*	*Rocks*	*Mineral Resources*
Quaternary		Recent	soils, sd., gravel	Sand, Clay, Gravel
		Cape May	sd. cl. gravel	SAND and GRAVEL, Water supply large
		Pensauken	sd. gravel. cl.	Sand and gravel
		Glacial	till, sd. gravel, cl.	SAND and GRAVEL, Building stone
Tertiary (U)		Bryn Mawr	sd. cl. gravel	Sand and gravel
Cretaceous		Patapsco	cl. sd. gravel	Clay, sand and gravel
Triassic	Newark (U)		red ss. sh. cgl.	Brown sandstone ("brownstone"), "Potomac marble," Baked shale, sandstone and limestone, lead
		(intrusives)	diabase, trap	CRUSHED STONE, trap, "black granite," MAGNETIC IRON ORE, copper, gold, silver, cobalt
Permian	Dunkard (L)	Greene	coal measures	sandstone, shale, clay, limestone, coal
		Washington	coal measures	Coal, sandstone, limestone, shale, clay
Pennsylvanian	Pittsburgh (U)	Monongahela	coal measures	COAL, limestone, sandstone, shale, clay
		Conemaugh	coal measures	ANTHRACITE, SANDSTONE, shale, limestone, bituminous coal, clay, oil, gas
		Allegheny	coal measures	COAL, ANTHRACITE, CLAY, LIMESTONE, SANDSTONE, shale, iron, oil, gas
	Pottsville (L)		coal measures	SANDSTONE, CLAY, Anthracite, Coal, shale, iron, glass sand, Building stone, oil, gas, Salt water

PENNSYLVANIA'S ROCKS AND MINERAL RESOURCES IN ORDER OF AGE—Continued

System	*Series*	*Group*	*Rocks*	*Mineral Resources*
Mississippian	Chester	Mauch Chunk	red sh. and ss. lst.	Shale, Sandstone, manganese, iron
	Meremec	Loyalhanna	limy ss.	Crushed stone, mineral wool
		Burgoon	ss. sh.	Oil and gas, building stone
	Waverly	Shenango	sh. ss.	oil, gas, building stone
		Cuyahoga	sh. ss.	oil, gas
	(Pocono)	Berea (Corry)	sandstone	oil, gas, Building stone
Devonian	U. Devonian	Catskill phase	red ss. and sh.	oil and gas, flagstone, sandstone, shale
		Chemung phase	ss. and sh.	OIL and GAS, flagstone, iron
		Portage phase	dark sh.	gas, brick clay
		Genesee	black sh.	limestone
		Tully	lst.	Sandstone, shale, Building stone
	M. Devonian	Hamilton	sh. ss. lst.	iron ore, limestone
		Marcellus	dark sh. lst.	
	L. Devonian	Oriskany	ss. chert, lst.	GAS, GLASS SAND, Iron, Molding sand, lead, white clay, Building stone
		Helderberg	lst. and sh.	Limestone, white clay, lime, Building stone
Silurian	Cayuga	Keyser	shy-lst. ss.	
		Tonoloway	shy-lst.	
		Wills Creek	sh.	ROCK SALT
		Bloomsburg	red sh. and ss.	Brick shale
	Niagara	McKenzie	lst.	
		Rochester	sh. ss.	
		Rose Hill	red sh. ss. and qtzite.	IRON ORE, Brick shale
		Tuscarora	qtzite.	SILICA REFRACTORIES, Building stone
Ordovician	Cincinnati	Juniata	red ss. and sh.	
		Bald Eagle	ss.	building stone
		Reedsville	sh.	brick
		(Martinsburg)	sh. sl. ss. lst.	SLATE, brick
	Mohawk	Trenton	lst.	CEMENT, LIME
		Lowville	pure lst.	LIME, FLUX, Cement
	Blount	(lacking)		
Canadian	Chazy	Stones River	pure lst.	LIME, CEMENT, FLUX
	Beekmantown	Bellefonte	dol-lst.	
		Axemann	lst.	Ag-lime
		Nittany	dol-lst.	ZINC, Lead, Building stone, iron
		Stonehenge	lst.	White clay
	Ozark	Larke	dol-lst.	
		Mines	dol-lst.	white clay
		Gatesburg	dol.	iron, white clay
Cambrian	U. Cambrian	Warrior	lst.	
	M. Cambrian	Elbrook	dol-lst.	Building stone, barite
		Waynesboro	sdy-lst.	barite
	L. Cambrian	Tomstown	sdy. lst. and dol.	IRON, Building stone, manganese
		Harpers	qtzite., ss.	White clay
		Chickies	qtzite, ss. cgl.	SILICA REFRACTORIES, Building stone
age?	Glenarm	Peach Bottom	slate	SLATE, Building stone
		Cardiff	cgl.	
		Peters Creek	schist, qtzite.	Building stone
		Wissahickon	schist	BUILDING STONE
		Cockeysville	lst. (marble)	Building stone, lime, marble
		Setters	ss. and sh. qtzite.	Building stone
age?		intrusives	granite, etc.	Building stone, feldspar, lead, zinc
Pre-Cambrian		Hartley	gneiss	building stone
		Baltimore	gneiss	BUILDING STONE
		Franklin	marble, gneiss	Building stone (marble), graphite
		intrusives and extrusives	granite, etc. rhyolite, etc.	Building stone Building stone, crushed stone

COAL

By GEO. H. ASHLEY

Coal is Pennsylvania's greatest mineral resource, not only for its fuel value but because it draws to itself many other industries to which it is basic. Coal is the primary reason for the State's vast iron and steel industry; its zinc industry and scores of others. Not only that, the steel industry calls for other industries; limestone for flux, sand for molding, coke for heating, and by-product coking yields gas and tars that make an ever expanding circle of industry. The Pittsburgh coal bed, including portions in West Virginia, Ohio, and Maryland, has been estimated to be the most valuable single mineral deposit in the world.

Kinds. Pennsylvania coal, because of its history, falls into several ranks. It is a "dry" coal, carrying ordinarily only 2 to 3 percent of moisture. Around Pittsburgh and northward, the coal is a high-volatile, having more than 30 percent volatile matter on the dry, mineral-free basis (mineral = ash × 1.1); in the middle counties, the coal is a medium-volatile, having 23 to 31 percent volatile matter. The eastern coal counties contain low-volatile coal having less than 23 percent volatile matter on the dry, mineral-free basis. At the western end of the anthracite field is semi-anthracite having from 8 to 14 percent volatile matter and being non-agglutinating. East of that is anthracite having less than 8 percent volatile matter. The reason for this dates back to the time of rock folding at the end of Coal Measure time. Two factors were involved. The pressure that produced the folding is believed to have come from the southeast, resulting in the rocks in the southeast part of the State being thoroughly crushed and metamorphosed. Westward and northwestward, the energy of the compressing force spent itself in folding the rocks and decreased in those directions. This shows, first in the decreasing degree of folding in those directions, and second in decreasing devolitization of the coal, so that the percentage of carbon decreases westward from Allegheny Mountain as the percentage of volatile matter left in the coal increases. The second factor was the increasing thickness and coarse-grained character of the pre-Coal Measures sediments toward the east, and toward the old land surface from which they were derived. The result of this was that in southeastern New York and northeastern Pennsylvania these massive rocks formed a buttress (Catskill Mountains and Pocono Plateau) that resisted folding and against which the folding forces pressed with increased intensity, resulting in the Pennsylvania anthracite fields, the extreme folding west of the buttress by which the anthracite fields were preserved, and an increasing percentage of carbon toward the buttress.

Anthracite Colliery
by John W. Raught

Distribution. Anthracite occurs in four irregular basins (see map) in the northeast part of the State, called the Northern, Western Middle, Eastern Middle, and Southern basins or fields. These basins are the bottoms of deep folds in which the coal beds and adjoining rocks were folded at the end of Carboniferous time. The tops of the folds were eroded and carried away during the long period of erosion that followed folding. Bituminous coal underlies most of the western part of the State and occurs in detached, hilltop basins in the northern part of the State.

Occurrence. Coal occurs in beds 1 inch to 100 feet thick, some of limited extent, some covering thousands of square miles. Most of the bituminous beds are from 1 to 4 feet thick. About 60 bituminous coal beds occur in Pennsylvania of which only 10 are widely mined. The anthracite beds average much thicker, the maximum being 114 feet with 105 feet of coal.

Bituminous Coal Tipple
by Ludwig Henning

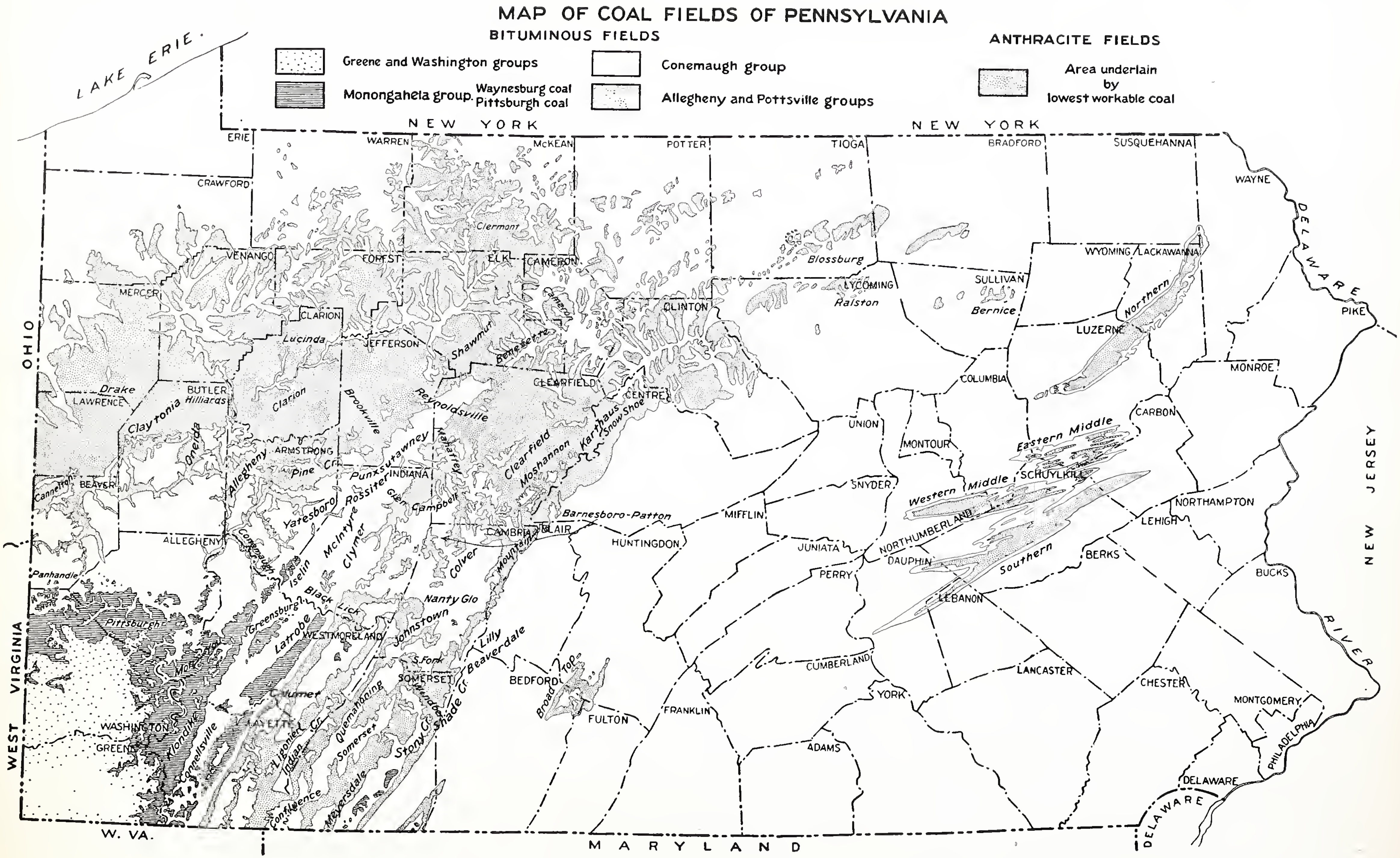
MAP OF COAL FIELDS OF PENNSYLVANIA
BITUMINOUS FIELDS
Greene and Washington groups
Monongahela group. Waynesburg coal Pittsburgh coal
Conemaugh group
Allegheny and Pottsville groups
ANTHRACITE FIELDS
Area underlain by lowest workable coal
LAKE ERIE
NEW YORK
NEW YORK
OHIO
WEST VIRGINIA
W. VA.
MARYLAND
DELAWARE
NEW JERSEY
DELAWARE RIVER
ERIE
CRAWFORD
WARREN
McKEAN
POTTER
TIOGA
BRADFORD
SUSQUEHANNA
WAYNE
PIKE
VENANGO
FOREST
ELK
CAMERON
MERCER
CLARION
JEFFERSON
CLEARFIELD
CLINTON
LYCOMING
SULLIVAN
WYOMING
LACKAWANNA
LUZERNE
MONROE
COLUMBIA
LAWRENCE
BUTLER
ARMSTRONG
INDIANA
CENTRE
UNION
MONTOUR
CARBON
BEAVER
ALLEGHENY
CAMBRIA
BLAIR
HUNTINGDON
MIFFLIN
SNYDER
JUNIATA
NORTHUMBERLAND
SCHUYLKILL
NORTHAMPTON
LEHIGH
BERKS
BUCKS
DAUPHIN
PERRY
LEBANON
WESTMORELAND
SOMERSET
BEDFORD
FULTON
FRANKLIN
CUMBERLAND
ADAMS
YORK
LANCASTER
CHESTER
MONTGOMERY
PHILADELPHIA
DELAWARE
WASHINGTON
GREENE
FAYETTE
Clermont
Blossburg
Ralston
Bernice
Northern
Eastern Middle
Western Middle
Southern
Cameron
Shawmut
Benezette
Lucinda
Drake
Claytonia
Hilliards
Clarion
Brookville
Reynoldsville
Oneida
Allegheny
Pine Cr.
Punxsutawney
Mahaffey
Clearfield
Moshannon
Karthaus
Snow Shoe
Barnesboro-Patton
Rossiter
Glen Campbell
Yatesboro
McIntyre
Clymer
Colver
Cannelton
Panhandle
Conemaugh
Iselin
Black Lick
Mountain
Nanty Glo
Johnstown
Lilly
Beaverdale
Broad Top
Greensburg
Latrobe
Pittsburgh
S. Fork
Shade Cr.
Wendber
Calumet
Quemahoning
Somerset
Stony Cr.
Ligonier
Indian Cr.
Klondike
Connellsville
Confluence
Meyersdale

FIGURE 5

Coal beds. The list of coal beds that follows is as previously given, but the correlation as between the bituminous and anthracite fields is revised to agree with correlations made but not yet published by a Correlation Committee of the National Research Council on Pennsylvanian Strata. The State Geologist has proposed that the boundary between the Allegheny and the Pottsville in the bituminous fields be drawn at the base of the Lower Kittanning coal or its underclay. That has not been done in this report to avoid the many contradictions it would involve with previously published reports. (Chart next page).

Bituminous coal reserves. In 1881, H. M. Chance estimated the bituminous reserves by beds. His summary follows:[1]

	Net tons
Beds over 6 feet thick	10,957,200,000
Beds from 3 to 6 feet thick	19,586,800,000
Beds from 2 to 3 feet thick	3,300,200,000
Total	33,844,200,000

This estimate takes no account of beds less than 2 feet thick, of beds between 2 and 3 feet thick below water level, or of beds 3 to 6 feet thick more than 150 feet below water level.

In 1913, M. R. Campbell estimated the coal in Pennsylvania for the 13th International Geological Congress. His figures revised up to the end of 1917 were: Know area bituminous coal 14,200 square miles, anthracite 484 square miles.

	Metric tons	*Net tons*
Bituminous coal	93,080,000,000	102,502,084,000
Semi-bituminous coal	9,074,000,000	10,002,270,200
Anthracite	19,056,300,000	21,005,949,000
Total	121,210,300,000	133,510,303,200

In 1921-22, John F. Reese estimated the reserves for most of the bituminous coal counties, based on planimeter measurements of coal areas on each bed and averaging of available coal-thickness measurements. These were published in mimeograph form as fast as each county was completed. In 1926, J. D. Sisler estimated the counties not previously studied and the whole was published by the Pennsylvania Survey in 1928 as Bulletin M 6, Part III, Bituminous Coal Resources. The figures are summarized in the following table (M6, Part III, page 7).

SUMMARY

BITUMINOUS COAL RESOURCES IN PENNSYLVANIA BY COUNTIES (net tons 1928)

County	*Original deposit*	*Mined out and lost*	*Recoverable*
Allegheny	3,194,820,000	969,200,000	1,498,948,000
Armstrong	3,750,700,000	107,290,000	2,491,100,000
Beaver	1,261,797,000	7,650,000	651,517,000
Blair	78,516,000	23,900,000	36,508,000
Bradford	44,440,000	14,500,000	15,514,000
Broad Top Field	414,954,000	41,850,000	252,918,000
Butler	4,154,807,000	39,300,000	2,257,511,000
Cambria	5,383,000,000	466,900,000	3,638,080,000
Cameron	61,500,000	235,000	33,561,000
Centre	514,485,000	75,250,000	275,076,000
Clarion	2,042,800,000	60,000,000	1,262,300,000
Clearfield	3,992,000,000	308,210,000	2,165,400,000
Clinton	114,380,000	17,221,000	54,580,000
Elk	559,781,000	54,775,000	300,473,000
Fayette	5,229,734,000	899,544,000	2,604,400,000
Greene	9,464,215,000	42,390,000	6,276,251,000
Indiana	6,339,400,000	299,200,000	4,288,700,000
Jefferson	3,334,900,000	279,400,000	2,123,400,000
Lawrence	1,007,866,000	16,445,000	484,020,000
Lycoming	72,000,000	7,000,000	40,000,000
Mercer	499,680,000	80,000,000	224,540,000
McKean	422,865,000	1,615,000	226,303,000
Somerset	6,091,800,000	187,384,000	3,986,900,000
Tioga	155,432,000	48,000,000	55,660,000
Washington	10,526,023,000	557,763,000	5,481,680,000
Westmoreland	6,381,504,000	1,218,141,000	3,297,500,000
Total	75.093,459,000	5.823,163,000	44,022,840,000

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[1] Day, David T., Mineral Resources U. S., 1886, p. 317.

TABLE OF COAL BEDS AND PRINCIPAL LIMESTONES IN PENNSYLVANIA

SYSTEM	SERIES	GROUP	*Bituminous coal field*	*Broad Top field*	*Southern Anthracite field*	*Northern Anthracite field*
PERMIAN	LOWER PERMIAN OR DUNKARD	GREENE 750 feet	Windy Gap			
			Gilmore			
			Nineveh			
			Dunkard			
		WASHINGTON 400 feet	Jollytown			
			Washington limestone			
			Washington A.			
			Washington			
			Waynesburg A.			
PENNSYLVANIAN	UPPER PENNSYLVANIAN OR PITTSBURGH	MONONGAHELA 400 feet	Waynesburg (6)*			
			Uniontown			
			Benwood limestone			
			Sewickley (8)			
			Redstone			
			Pittsburgh (2)			
		CONEMAUGH 600 to 900 feet	Little Pittsburgh		? Brewery	Auble
			Franklin		? Salem	Snake Island
			Little Clarksburg	Rogers	? Tunnel	Abbott
			Wellersburg		? Peach Mt.	Kidney
			Barton	McCue Basin	? Tracy	Hillman
			Ames limestone		? Diamond	
			Harlem		? Orchard	Orchard
			Bakerstown	Mosquito Hollow	? Primrose	
			Thomas		? Holmes	Lance
			Brush Creek	Phipps		
			Mahoning	Speer		
		ALLEGHENY 250 feet	Upper Freeport (1)	Kelly	? Mammoth	Baltimore
			Lower Freeport (4)	Dudley	? Skidmore	Marcy
			Upper Kittanning (5)	Barnettstown		
			Middle Kittanning (7)	Twin bed	? Seven-foot	Clarke
			Lower Kittanning (3)	Barnett	Buck Mountain	Red Ash
			Vanport limestone	a	Pottsville	Pottsville
			Snodgrass			
			Clarion			
			Pardoe or Brookville (9)			
	LOWER PENNSYLVANIAN OR POTTSVILLE	180 to 1,450 feet	Homewood sandstone	b		
			Upper Mercer (10)	Gordon		
			Lower Mercer			
			Quakertown	c		
			Sharon			
					Lykens No. 1	
					Lykens No. 2	
					Lykens No. 3	
					Lykens No. 4	
					Lykens No. 5	
					Lykens No. 6	
					Lykens Valley	

a, b, c—Pottsville—Allegheny boundary

a—according to modern correlation

b—as used in the Beaver Valley

c—as used in Allegheny Valley. Homewood sandstone of Beaver Valley equals Clarion sandstone of Allegheny Valley

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* Rank of reserves remaining as of Jan. 1, 1927 (Pa. G.S. Bull. M 6, pt. III) pp. 8-9.

In some of the reports on later detailed work, the estimates of coal reserves were simply copied from the 1922-26 results. In some cases the reserves were re-estimated using the fuller data then available. In some instances these later figures differ materially from the earlier. In others the difference is very slight. As most of the area concerned has not been restudied in detail since the Reese-Sisler estimates, those figures must form the basis of any present re-estimates. However, the more recent estimates were compared with the old figures to determine whether the later and more accurate work tended to increase or decrease the earlier figure—after allowing for depletion during the intervening years. In such a comparison, the Pittsburgh district was considered separately from the rest of the fields.

The table which follows gives Reese's estimates of 1922 on Fayette County in net tons. They are then changed to bring them down to 1938 for comparison with figures obtained by F. T. Moyer (Pa. G.S. Bull. C 26, p. 416 et seq.) after a detailed survey of the county. Moyer's figures for exhaustion are based on planimeter measurements of worked out areas, following the same method that was used in determining the original deposit:

REESE ESTIMATES, FAYETTE COUNTY 1922 *

Bed	*Original deposit*	*Exhaustion*	*Recoverable*
Waynesburg	316,854,000	3,216,000	199,800,000
Sewickley	194,175,000	10,132,000	123,600,000
Redstone	151,380,000	....	75,700,000
Pittsburgh	2,087,772,000	878,030,000	919,300,000
Freeport	2,088,153,000	1,650,000	1,029,000,000
U. Kittanning	89,280,000	2,016,000	59,000,000
L. Kittanning	302,120,000	4,500,000	198,000,000
Total	5,229,734,000	899,544,000	2,604,400,000

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* Pa. Geol. Survey Bull. M 6, Pt. III, p. 88.

To compare these figures with the later figures of Moyer, the production and loss from 1922 to 1938 must be added to depletion and subtracted from reserves. About 1,000,000,000 tons of coal have been mined and accounted for in Fayette County to 1938 of which 95 percent, or 950,000,000 tons, was from the Pittsburgh bed. But, if, as reported by Moyer, the depletion on that bed as determined from mine maps was 1,510,000,000 tons, only 63 percent of the original bed was accounted for in tons produced, a much larger rate of loss than has usually been assumed, based on studies of mine losses made for the U. S. Coal Commission in 1923 (Pa. G.S. Bull. M 4). Probably at least part of the difference lies in the "original coal" estimates including poor bottom and top coal left in the mine, and not included in the Commission estimates. To play safe a loss of 33⅓ percent has been used in the other counties on the Pittsburgh bed, and 50 percent on all other beds, as discussed later. These losses were used in bringing Reese's figures up to 1938. As thus revised the figures compare as follows:

COAL ESTIMATES, FAYETTE COUNTY 1938

Bed	*Original deposits*	*Exhaustion*	*Recoverable*
Reese (1938)			
Pittsburgh	2,088,000,000	1,382,000,000	416,000,000
Other beds	3,142,000,000	40,000,000	1,667,000,000
Total	5,230,000,000	1,422,000,000	2,083,000,000
Moyer (1938)			
Pittsburgh	1,990,000,000	1,510,000,000	418,000,000
Other beds	5,580,000,000	365,000,000	3,016,000,000
Total	7,570,000,000	1,875,000,000	3,434,000,000

Except for a larger ratio of losses, the figures for the Pittsburgh bed are very close; for the other beds far apart. Because of limited mining on the other beds, Moyer's figures may be too large. Because the information obtainable on the other beds is not as complete as could be desired, it has seemed wise and conservative for the Pittsburgh district outside Fayette County to use the Reese figures of reserves on the beds other than Pittsburgh without reduction for exhaustion in the intervening years. The figures for Fayette County are taken from Moyer's estimates, reduced by the production and losses from 1937-1942. The 4.7 percent production for Fayette County on beds other than Pittsburgh bed was determined from the production reports by mines as given in the annual report of the Secretary, Department of Mines, for 1928.

For the counties outside the Pittsburgh district, comparisons were made with the figures obtained in recent studies in the Smicksburg, Punxsutawney, and Curwensville quadrangles and for southeastern Clearfield County. The following table compares the figures for the original deposits for three beds for those townships that are wholly within the Smicksburg quadrangle and, therefore, comparable.

Notice here that the Upper Freeport bed reveals only one-tenth as much coal today as it was thought to have in 1922; the Lower Freeport less than half; but the Lower Kittanning has more than four times as much. The Shaffner figures include much data obtained from drill records not available in 1922. The recent figures total only 57 percent of the older figures.

A similar study of the original deposits of the whole townships included in the Punxsutawney and Curwensville quadrangles also is given, in net tons:

COAL RESERVES, SMICKSBURG QUADRANGLE

Original deposit in net tons, by M. N. Shaffner

Townships	*Upper Freeport*	*Lower Freeport*	*Lower Kittanning*	*Total*
East Mahoning	2,473,000	20,899,000	56,045,000	79,417,000
Perry	...	63,632,000	62,789,000	126,421,000
Porter	10,217,000	33,203,000	37,103,000	89,523,000
North Mahoning	...	19,547,000	47,862,000	67,409,000
South Mahoning	18,333,000	...	53,483,000	71,816,000
West Mahoning	9,835,000	30,525,000	56,477,000	96,837,000
Total	40,858,000	167,806,000	313,759,000	531,423,000
	Bulletin M 6, Pt. III, pp. 104, 105, 112, 113			
East Mahoning	102,500,000	66,900,000	....	169,400,000
Perry	45,000,000	52,400,000	43,600,000	141,000,000
Porter	17,500,000	46,600,000	27,900,000	92,000,000
North Mahoning	105,700,000	48,000,000	....	153,700,000
South Mahoning	110,800,000	82,000,000	....	192,800,000
West Mahoning	103,400,000	79,000,000	....	182,400,000
Total	484,900,000	374,900,000	71,500,000	931,300,000

COAL RESERVES, PUNXSUTAWNEY AND CURWENSVILLE QUADRANGLES

County and Township	*Original deposit*		*Reserves*	
	1922	*1925*	*1922*	*1925*
Indiana County				
Banks Township	166,600,000	198,900,000	111,300,000	78,000,000
Canoe Township	116,900,000	235,800,000	66,600,000	59,000,000
Grant Township	123,600,000	147,150,000	83,600,000	39,750,000
Montgomery Township	283,900,000	229,050,000	187,900,000	70,250,000
Jefferson County				
Bell Township	193,100,000	189,000,000	127,300,000	68,000,000
Gaskill Township	123,700,000	122,850,000	73,200,000	40,100,000
Clearfield County				
Bell Township	308,200,000	317,250,000	182,500,000	109,000,000
Burnside Township	207,600,000	336,500,000	112,100,000	84,750,000
Chest Township	309,000,000	222,750,000	160,100,000	47,250,000
Ferguson Township	83,200,000	145,575,000	44,100,000	34,000,000
Greenwood Township	55,300,000	120,425,000	29,200,000	24,625,000
Jordan Township	206,700,000	236,250,000	114,800,000	94,750,000
Penn Township	90,000,000	176,925,000	51,300,000	48,625,000
Pike Township	79,000,000	85,950,000	40,800,000	26,750,000
Total	2,346,000,000	2,764,375,000	1,384,800,000	824,850,000

The estimate of original deposits based on the more abundant data is 17 percent above earlier figures, but the estimates of reserves, including only coal more than 2 feet thick is 40 percent less than the earlier figures, as against 43 percent lower in the Smicksburg quadrangle. The difference in the figures appears to be in that the detailed reports take account of areas of thin coal—below 2 feet—more fully than in the 1922 estimate, based on drill records, while the areas of coal over 2 feet were frequently found to be much smaller than previously estimated. Thus, a summary of coal by thickness for the Punxsutawney and Curwensville quadrangles, in which the thicknesses in many drill holes were combined with measurements in mines and outcrops, shows:

THICKNESS STUDY, PUNXSUTAWNEY AND CURWENSVILLE QUADRANGLES

Thickness	*Punxsutawney Quad.*		*Curwensville Quad.*	
in feet	*Net tons*	*%*	*Net tons*	*%*
Less than 2	767,410,000	45	685,670,000	46
2 to 3	360,970,000	21	638,610,000	43
3 to 4	437,184,000	25	124,035,000	9.5
Over 4	158,400,000	9	21,600,000	1.5
Total	1,723,964,000	100	1,469,915,000	100

The difference in the ratios has been strongly reflected in the character of mining in the two areas, Punxsutawney having been the scene of large-scale mining, now mostly over, while the Curwensville area has had only small mines with one or two exceptions. In both areas large-scale mining has greatly declined, owing to the exhaustion of the thicker beds. The extent to which mining is and has been confined to the thicker beds is shown by a study of the mines of the Punxsutawney quadrangle as of 1904, when mining was about at its height in that area. On coal less than 3 feet, no commercial mines; coal 3-4 feet, 16 percent; 4-5 feet, 26 percent; over 5 feet, 58 percent.

Some other comparisons seemed to confirm the ratios arrived at above. Thus in Rush Township, Centre County, the 1926 figures show for the Freeport coal: Original deposit 5,760,000 tons; mined out and lost 2,500,000; recoverable 1,467,000 tons. But it is probable that in 1926, only crop coal was still available and not all of that, possibly 467,000 tons, if so much. Or, the same bed in Decatur Township, Clearfield County, in 1922 was given: Original deposit 76,700,000 tons; mined out and lost 66,900,000 tons; recoverable 7,500,000 tons. At that time pillar robbing and crop mining had been active for many years on that bed. Probably, 1,500,000 tons would cover odds and ends of unmined coal on that bed in that township at that time. The State Department of Mines listed no commercial mines in that bed in that township in 1928.

On the assumption that the studies here presented are characteristic of the bituminous coal field of Pennsylvania as a whole, the following procedure was followed: (1) The Fayette County figures are based on Moyer's estimates brought up-to-date. (2) For the Pittsburgh bed, former estimates of reserves were reduced to allow for coal mined out since 1922 and losses, which were estimated at 33⅓ percent of bed tonnage. (3) Original tonnage was increased 10 percent over 1922-26 figures for all counties. (4) Reserves as of 1922-26 were reduced 40 percent on all beds except the Pittsburgh. From that figure was deducted the coal mined out from 1922 to 1942 inclusive, as tabulated by the United States Bureau of Mines, plus computed bed losses. These were on the basis of 33⅓ percent for the Pittsburgh bed, based on Moyer's estimates and 50 percent for the other beds

BITUMINOUS COAL RESERVES IN PENNSYLVANIA (millions of net tons)

Counties	*Original deposit*	*Mined out and lost*	*Reserves over 2′*	*In beds over 3′*	*In beds 2-3′*	*In beds 1-2′*
Allegheny	3,515	1,370	1,095	500	595	525
Armstrong	4,125	220	1,275	920	355	1,315
Beaver	1,390	17	280	80	300	495
Bedford	285	40	80	65	15	60
Blair	85	30	15	5	10	20
Bradford	50	20	6	1	5	12
Butler	4,570	75	1,320	320	1,000	1,590
Cambria	5,920	865	1,700	300	1,400	2,490
Cameron	70	...	20	...	20	25
Centre	565	105	145	25	120	160
Clarion	2,245	80	710	110	600	715
Clearfield	4,390	435	1,175	175	1,000	1,390
Clinton	125	20	30	10	20	40
Elk	615	80	155	55	100	190
Fayette	7,565	2,000	2,730	1,400	1,330	1,420
Pittsburgh	1,990	1,630	335	335	...	...
Other beds	5,575	370	2,470	1,140	1,330	1,420
Fulton	33	1	11	4	7	10
Greene	10,610	173	4,775	3,000	1,775	2,830
Huntingdon	140	30	30	10	20	40
Indiana	6,973	533	2,340	800	1,540	2,050
Jefferson	3,670	350	1,200	300	900	1,060
Lawrence	1,110	25	285	40	245	350
Lycoming	80	7	24	4	20	24
Mercer	550	90	125	25	100	165
McKean	465	2	135	5	130	165
Somerset	6,700	400	2,170	770	1,400	2,065
Tioga	170	6	26	6	20	45
Washington	11,580	1,020	4,695	3,000	1,695	2,930
Westmoreland	7,020	1,595	2,340	1,500	840	1,220
Total	84,616	9,589	28,892	13,430	15,562	23,401

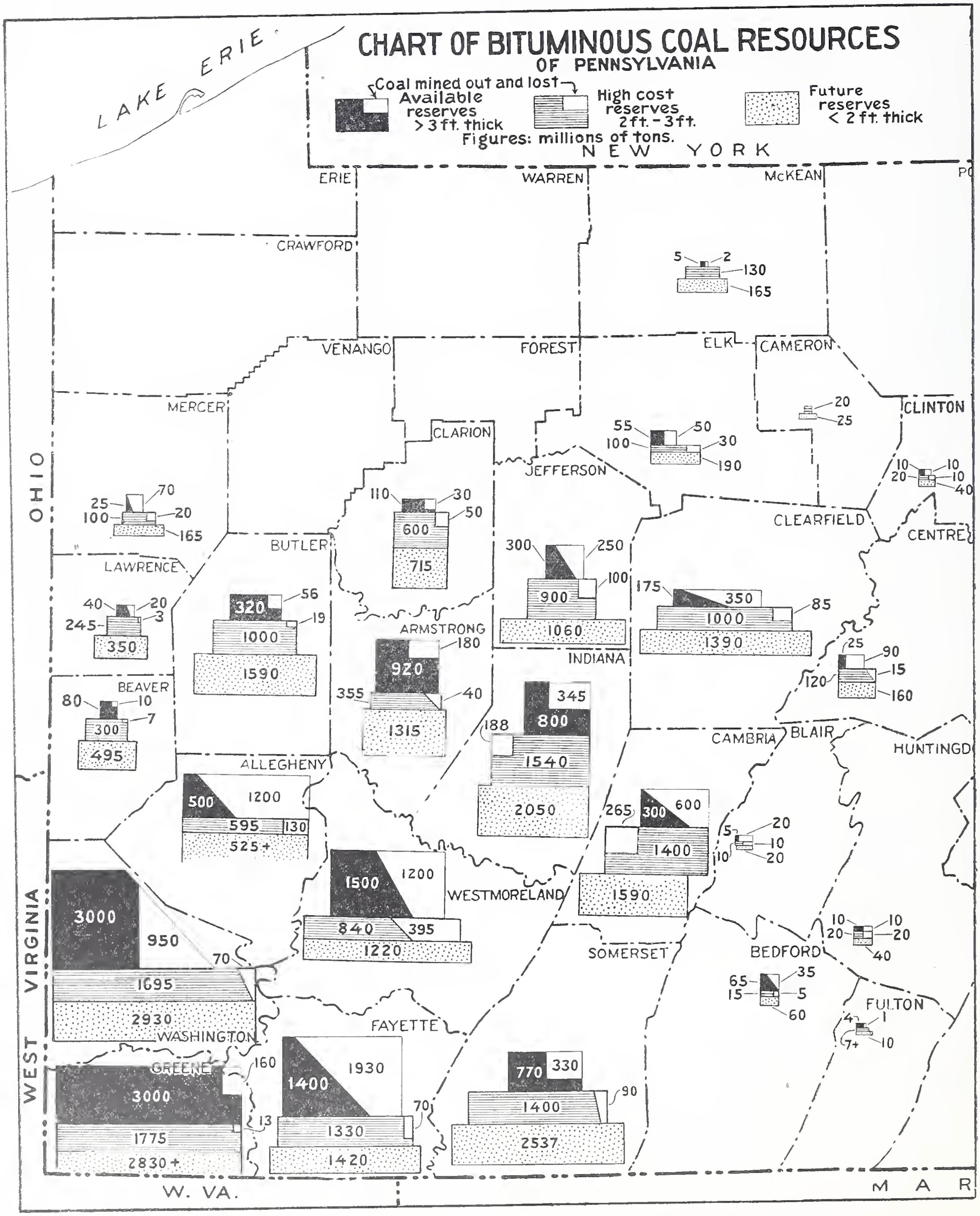

Figure 6. DIAGRAM SHOWING BITUMINOUS COAL RESOURCES, BY COUNTIES

to be in line with the actual losses discovered to exist in Fayette County. (5) The division of reserves was obtained by first subtracting the sum of estimated reserves and mined out and lost coal from the figure for original deposit. The result divided by two was placed in the future reserve column. The Reese-Sisler figures for each county were then reviewed to determine roughly the proportion of the rest of the original deposit that was above 3 feet and that between 2 and 3 feet. Where the thickness was given as 24 inches or 36 inches, the estimate was split in half, one-half added to estimates above those thicknesses, the other half to that below those thicknesses. (6) To determine the proportion of coal produced from beds above or below 3 feet, a check of typical counties by individual mines was made from the Secretary of Mines reports or based on personal knowledge of which beds are and have been mined. Too much weight should not be given to these ratios, as time did not permit a detailed study.

The results are summarized in the previous table. In order to give a practical figure, the reserves are divided into: 1. future reserves, coal between 1 and 2 feet thick or otherwise (thick partings or low-grade) not commercially minable today, estimated 50 percent recovery; 2. immediate reserves, coal between 2 and 3 feet thick, high-cost coal which is minable for local use, or on a larger scale if the higher cost can be met; and 3. available coal, which should be commercially minable under present prices and costs. Because of the many uncertainties involved, figures are given in the nearest five million tons except where very small.

Anthracite reserves. The first careful estimates of anthracite original deposit, waste, and reserves were made in 1890-91 by the Coal Waste Commission of Pennsylvania, appointed under an Act of Legislature. That commission estimated the original tonnage by dividing the area underlain by coal into 59 "areas," each lying between two carefully drawn cross sections (Second Geological Survey of Pennsylvania). On each of these sections the length of each coal bed was measured and multiplied by the thickness, giving a total figure of bed-feet. The average of the two end sections was assumed to hold for the intermediate "area." The results in gross tons are summarized as follows: (Commission report, pages 148-149.)

In 1922-23 a new estimate was made by Dever C. Ashmead in connection with a study of coal mining

ANTHRACITE RESERVES 1890-91

Region	*Estimated original content*	*Amount used up, 2½ times production*	*Estimated contents remaining*	*Available marketable coal in ground*
Wyoming	5,700,000,000	1,052,500,000	4,647,500,000	1,859,000,000
Lehigh	1,600,000,000	406,250,000	1,193,750,000	477,500,000
Schuylkill	12,200,000,000	796,250,000	11,403,750,000	4,561,500,000
Total	19,500,000,000	2,255,000,000	17,245,000,000	6,898,000,000

ANTHRACITE RESERVES 1922-23

Fields	*Estimated original contents*	*Estimated contents removed*	*Estimated remaining contents*
Northern	5,447,623,000	2,170,860,000	3,276,763,000
Eastern Middle	612,448,000	363,820,000	248,628,000
Western Middle	4,596,795,000	1,023,770,000	3,573,025,000
Southern	10,114,050,000	857,790,000	9,256,260,000
Total	20,770,916,000	4,416,240,000	16,354,676,000

ANTHRACITE RESERVES BY FIELDS AS OF JANUARY 1, 1943

(In thousands of net tons)

	Northern	*Eastern Middle*	*Western Middle*	*Southern*	*Total*
Reserves as of Jan. 1, 1922, Ashmead (gross tons)	3,276,763	248,628	3,573,025	9,256,260	16.354,676
Same in net or short tons	3,669,975	278,463	4,001,788	10,367,011	18,317,237
Production 1922-1942 (net tons)	715,640	127,230	279,452	194,492	1,316,814
Ratio of losses in percentage	33	30.6	41.9	51	....
Depletion	1,068,119	183,328	480,984	396,922	2,129,353
Reserves as of Jan. 1, 1943	2,602,000	95,000	3,521,000	9,970,000	16,188,000
Life of field based on average depletion (years)	51	10.8	153	526	160
Average annual depletion over 21 years	50,857	8,730	22,904	18,954	101,445

losses for the U. S. Coal Fact Finding Commission. The finding of additional reserves justified increasing the original total to 20,770,916,000 gross tons. Ashmead's estimate by fields is given in gross tons.

In 1938 the writer reestimated the reserves as of January 1936. This was based on Ashmead's figures brought down to January 1, 1936. Like the last, these estimates were by fields and used the same percentage of recovery figures. Those figures are here brought down to January 1, 1943 and converted into net tons to conform to the present practice and the law.

To convert these figures into a county basis, as Ashmead's figures were on a field basis only, it was necessary to go back to the Coal Waste Commission figures of 1890, as they were computed on 59 small map areas. Areas lying wholly within a county were used as given. The coal in areas lying in more than one county was divided in proportion to the surface areas in the several counties (column 1). As the Ashmead figures are a little larger, the figures based on the Commission estimates were increased or decreased accordingly (column 2). The coal in the Northern field was decreased by Ashmead, the others increased (column 3). The figures for each county were then changed from gross to net tons (column 4). Two minor changes in the total were made; the coal in Dauphin and Lebanon Counties was decreased under the Waste Commission total by 400,000,000 long tons to allow for the lack of coal shown by later surveys and tests, and the coal in Sullivan, Susquehanna, and Wayne Counties increased slightly to a little more than cover the coal already reported recovered or lost from those counties. Thus, against a volume of coal estimated in 1892 to be 19,500,000,000 gross tons, Ashmead estimated 20,770,916,000 gross tons. This is reduced here to 20,398,000,000 gross tons or 23,060,000,000 net tons (columns 3 and 4).

The total production of each county was then determined from reports of the U. S. Geological Survey and U. S. Bureau of Mines (production before 1884 estimated) (column 5). These figures divided by recovery percentage (as determined by Ashmead) (column 6) gave the total exhaustion (column 7). Column 8 gives the coal left in the ground. Applying the percentage of recovery, column 9 gives the estimated recoverable coal in each county. Column 10 gives an average annual production in recent years based on a total production of 50,000,000 net tons. Column 11 gives the life of the coal in each county if that rate of production continues.

There are too many factors of uncertainty to give these figures any high value. Several counties draw from more than one field. To obtain accurate figures would require locating each mine as to county and field and totalling its production over the years. Modern stripping operations are exhausting less of the virgin coal for the tonnage of coal obtained than underground operation. No account is taken of "bootleg" coal, as no figures are available of such coal.

ESTIMATED RESERVES OF ANTHRACITE BY COUNTIES

Millions of gross tons				*Millions of net tons*							
Counties	1. *Original content 1892 map*	2. *Plus or minus*	3. *Revised original content 1944*	4. *Same as last*	5. *Estimated coal recovered 1820-1942*	6. *% recovery*	7. *Estimated coal exhausted 1943*	8. *Estimated coal left 1943*	9. *Estimated recoverable coal*	10. *Recent annual mining rate*	11. *Life in years*
Carbon	535	+16	551	620	152	.55	276	344	189	2.5	75
Columbia	480	+87	567	650	62	.58	107	543	315	.5	630
Dauphin and Lebanon	300 278	−400	178	200	61	.49	124	76	37	.2	185
Lackawanna	1,900	−40	1,860	2,200	1,047	.67	1,563	637	427	8.4	50
Luzerne	4,230	−200	4,030	4,560	1,706	.67	2,537	2,023	1,355	22.0	61
Northumberland	2,000	+300	2,300	2,600	367	.58	633	1,967	1,041	5.0	208
Schuylkill	9,700	+1,100	10,800	12,100	1,026	.49	2,093	10,007	4,903	11.3	434
Sullivan	30	+10	40	50	26	.60	43	7	4	.1	40
Susquehanna and Wayne	27 20	+25	72	80	47	.67	70	10	7	.2	35
	19,500		20,398	23,060	4,494		7,446	15,614	8,278	50.0	

REFERENCES:
Bituminous Coal Resources, by Reese, John F. and Sisler, J. D.: Pa. Geol. Survey Bull. M 6, pt. III, 1928.
Anthracite Losses and Reserves in Pennsylvania, by Dever C. Ashmead: Pa. Geol. Survey Bull. M 8, 1926.

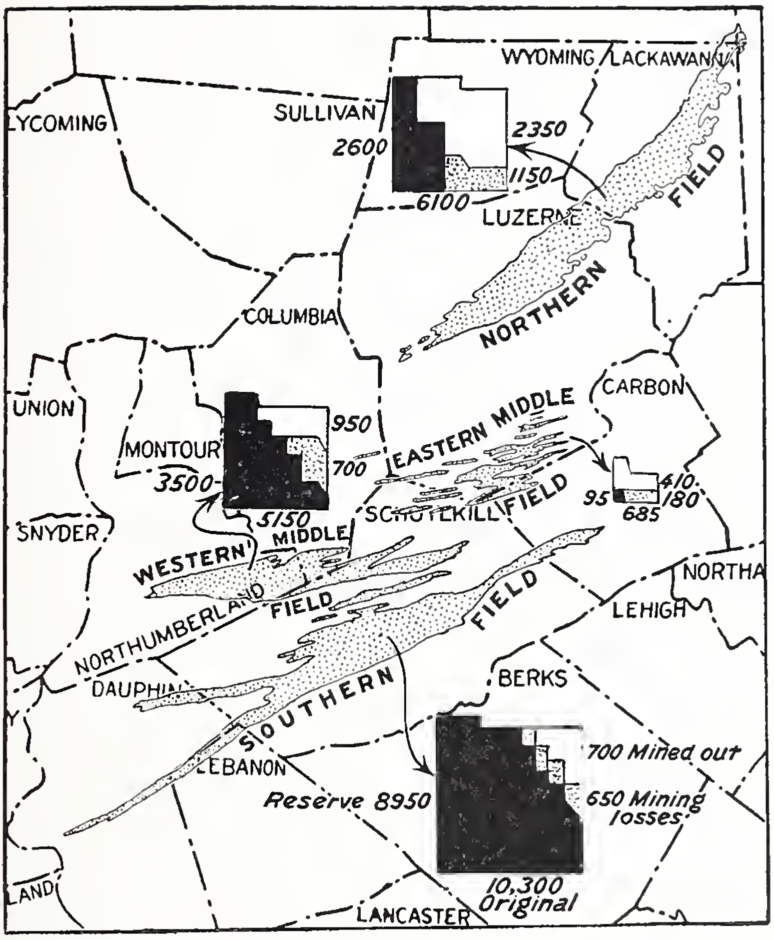

FIGURE 7. DIAGRAM SHOWING ANTHRACITE RESERVES

OIL AND GAS *

Although Pennsylvania produces only 1.2 percent of the nation's crude oil, it produces practically one-third of the nation's high viscosity index lubricating oil, for many purposes conceded to be superior to those made from any other type of crude oil, especially for aircraft-type engines. Pennsylvania's oil fields, therefore, have a strategic importance far greater than their size or production would imply.

Experience has shown that primary drilling and pumping of oil wells in Pennsylvania has recovered only 15 to 25 percent of the oil. Another 15 to 40 percent is being recovered from several fields by repressuring the oil sands with water, air, or gas, leaving at least half of the original content of oil in the sands. The estimates given herein indicate that of about 4,700,000,000 barrels of oil originally in the ground, a little over 1,000,000,000 barrels have been removed, leaving about 3,500,000,000 barrels still in the ground, of which one-half probably is obtainable from known pools by present known methods, but of which not more than one-tenth could be obtained at present price levels or even a little higher. One and one-fourth billion barrels could be obtained at much higher price levels or through the discovery of more economic methods of recovery, still leaving in the ground nearly 2,000,000,000 barrels to be recovered only by mining or some other process not yet developed.

Origin and occurrence. Oil and gas are thought to be derived from the partially decayed remains of marine life imbedded in sea-bottom muds, from which the oil and gas are derived by bacterial action and other processes still being studied. The oil and gas migrated by capillarity and compaction from the mud into adjoining bodies of sand in which gas, oil, and water tend to stratify, owing to differences in gravity and surface tension. The distribution of the oil in the western end of the State only, of gas east of that to Allegheny Mountain, and the lack of both east of Allegheny Mountain is ascribed to the differing intensity of the folding of the rocks from west to east. In some of the gas fields of Pennsylvania, notably those in the Oriskany sandstone, the gas is confined to the tops of anticlines, or to benches or other structural traps. In general the oil pools of Pennsylvania appear to be closely related to the porosity and permeability of the sand, and this in turn to surface conditions at the time the sand was deposited. Many of the deposits are confined to areas of shore deposits or offshore bars, where the sand was coarse and the resulting sandstone more than commonly porous.

During the deposition of most of the oil and gas sands of Pennsylvania (Upper Devonian time) the shore line was slowly migrating westward, so that conditions favorable for oil and gas accumulation migrated westward at the same time. As a result, as shown on the map of the oil fields, figure 8, the eastern sands are older, the western sands younger. Consequently, drilling in the western fields penetrates the younger sands laid down close to shore and now containing oil or gas locally, and below them finds a great thickness of fine-grained deposits that were laid down far from the earlier shore farther east. The bottom of the coarse-grained sandstones in any area, therefore, constitutes a "floor" that descends stratigraphically eastward. Below that floor no oil or gas may be encountered until certain deep beds, such as the Onondaga chert, Oriskany sandstone, Lockport dolomite, Medina sandstone, Trenton limestone, or others, are reached.

Stratigraphy of the oil and gas sands. The porous sandstones, or chert (Onondaga), referred to above,

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* Compiled by George H. Ashley from work of Stanley H. Cathcart, Parke A. Dickey, Lawrence S. Matteson, Charles R. Fettke, R. E. Sherrill, and Daniel A. Busch.

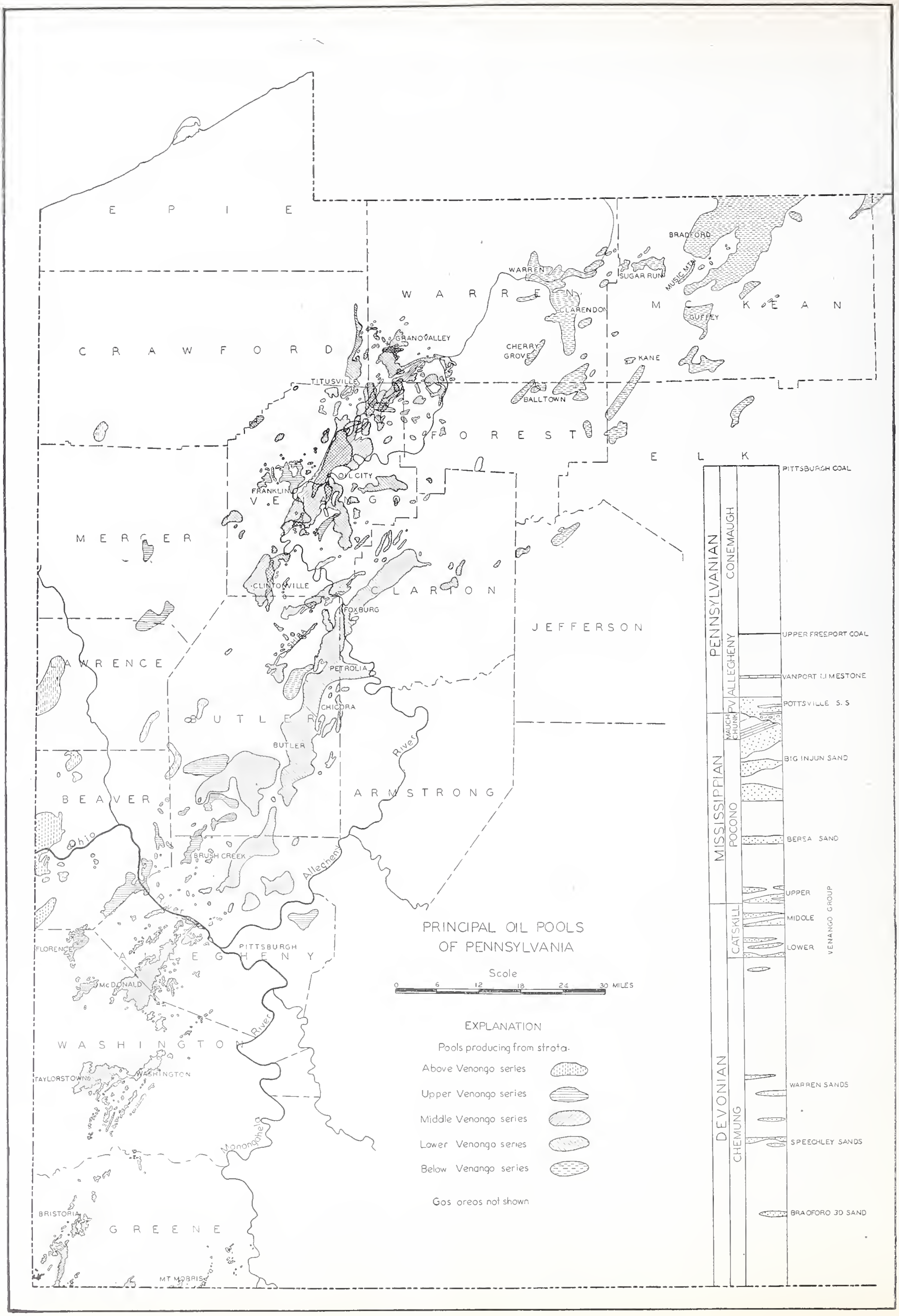


FIGURE 8. MAP OF THE PRINCIPAL OIL POOLS OF PENNSYLVANIA

occur at intervals in a section of rocks 12,000 feet thick at Pittsburgh and 16,000 feet thick at Allegheny Mountain in central Pennsylvania, and in age from Lower Ordovician to Coal Measures, but principally in the uppermost Devonian and lower Mississippian strata. For the reasons given above the oil pools are, as a rule, not widespread but quite restricted horizontally and vertically. An unconformity at the base of the Pennsylvanian—of which most of the surface rocks consist—renders variable the interval from any of the surface rocks to the underlying oil or gas sands. In the table of sands that follows, the top of the Venango First sand or top of the Hundred-foot sand has been chosen as the key horizon.

Outline of historic development. Oil (petroleum), known in Pennsylvania from surface seeps before white men came, was collected by the Indians and early settlers and used as medicine for rheumatism. In 1753 Peter Kaln described the oil spring on Oil Creek. In the first half of the 1800s oil encountered in wells drilled for salt found some market as medicine, lubricant, and for illumination, though in general it was considered a nuisance. In the 1850s, coal-oil (kerosene) distilled from coal began to be used extensively for illumination, selling in 1859 for 60 to 70 cents a gallon. In 1859, the Drake well near Titusville got oil at 69½ feet. By 1861, drilling had spread rapidly, many gushers flowed 3,000 to 4,000 barrels a day, and the price had declined to 10 cents a barrel. By 1865, drilling had spread to Greene County. The Bradford pool started in 1875, reached its maximum in 1881. From 1885 to 1891, large pools were found in Washington County, one well in the McDonald field flowing 730 barrels an hour. In 1891, production in Pennsylvania reached a peak of 31,424,000 barrels, and then declined rapidly (see statistics) By 1893, production was below 20,000,000 barrels and has never since reached that volume. By 1900, it was down to 13,258,000 barrels; in 1910 to 8,795,000 barrels, and by 1920 to 7,438,000 barrels and gave promise of declining more and more slowly to complete extinction.

Secondary recovery. As early as 1880, John F. Carll of the Second Pennsylvania Geological Survey suggested increasing the flow of oil by admitting water under pressure behind the oil to force it toward other wells that continued to pump. By the early 90's, small accidental or intentional flooding was done in the Bradford district, the effect of which by 1907 became appreciable in the production figures. But a plugging law to prevent the access of water to the sands, held back flooding until 1921, when a new law authorized flooding for secondary recovery by admitting water under pressure to the sand in a systematic way; then the recovery of the oil began on a large scale (see Pa. Geol. Surv. Bull. M 21, Bradford Oil Field). When the method spread to other fields, it proved successful in few pools. Then gas and air under pressure were tried in place of water, but with less success than with water in the Bradford pool. They did show that first drilling and pumping left much oil in the sand, some of which could be recovered by the use of air, gas, or water under pressure. Today the practice is well standardized, though several patterns of intake and producing wells are used. (See Pa. Geol. Surv. Bull. M 22.) See production statistics and figure 9 showing curve of production.

Drilling for Oil
by Christian J. Walter

This painting is of an old-fashioned wooden rig of moderate height. Modern rigs are steel tubing and angle irons.

Proven oil reserves. The proven oil reserves in Pennsylvania have been estimated many times, each time with greater care and the advantage of increased

OIL AND GAS SANDS OF PENNSYLVANIA

Interval in feet above and below top of Venango group

Systems	Series		Groups or Formations Old	Groups or Formations New	Stratigraphic names	Names of Oil and Gas sands	Fayette Co.	Greensburg	Allegheny Co.	Washington Co.	Beaver Co.	Mercer Co.	Erie Co.	Venango Co.	Warren Co.	Mc Kean Co.	Elk Co.	N.W. Potter Co.	Tioga Co.	S.E. Potter Co.	S.E. Jefferson Co.
PENNSYLVANIAN	Pittsburgh	XV	Monongahela		Pittsburgh coal		2000	2000	2000	1800	1450										
		XIV	Conemaugh		Morgantown sandstone	Murphy															
					Saltsburg sandstone	Little Dunkard, 1st Cow Run															
					Mahoning sandstone	Big Dunkard															
		XIII Allegheny	Allegheny		Upper Freeport coal		1400			1169											1160
					Freeport sandstone	Upper Gas, 2nd Cow Run															
					Kittanning sandstone	Middle Gas															
					Lower Kittanning coal		1180														985
	Pottsville	XII Pottsville	Pottsville		Vanport limestone	Vanport limestone			1145	946	700			875							
					Homewood sandstone	First Salt		1060	1070		550										
					Connoquenessing	Second Salt															
					Sharon (Olean) sandstone	Third Salt; Maxton										350					
MISSISSIPPIAN	Chester	XI M.C.	Mauch Chunk		Mauch Chunk shale	Red shale															
					Greenbrier limestone	Little lime	825		825	714											
			Meramec		Loyalhanna limestone	Big lime		870	780												
	Waverly	X Pocono	Burgoon		Burgoon sandstone	Big Injun; Mountain sand	700	800	700	696											700
			Cuyahoga		Patton red shale	Patton red shale															
					Shenango									390	410						420
					Sharpsville	Squaw	330														
					Orangeville	Papoose															
			Berea		Corry sandstone	Berea; 3rd Mountain sand		180?	150	188	240	170		230	250	250					
					Cussewago sandstone	Murrysville; Butler 30 ft.	130														130
DEVONIAN	Upper Devonian or Chautauqua	IX Catskill	Conewango	Oswayo	Riceville shale	"Red rock"															
				Venango	Woodcock sandstone	Venango 1st; 100 ft; Gantz; 50 ft.	0	0	0	0	0	0	0	0	0	0	0	0?	0?	0?	0
					Saegerstown shale	Lytle; Red Valley						150									
				Cattaraugus	Salamanca sandstone	Venango 2nd; 30 ft. Nineveh; ↑"Red beds"↓			130			190									130
					Amity shale	Boulder; Blue Monday, etc.															250
					Panama (Wolf Cr) sandstone	Venango 3rd; Gordon			300		225	360	300	280	280	300	316	400			
			Conneaut		Chadakoin formation	Fourth	480	350	350	352	285	400									
						Fifth			430												
						Sixth; Bayard			480												
						Elizabeth	560		530												600
		VIII Chemung			Hinsdale sandstone	First Warren						810									
					Girard shale	Second Warren						910									
					Cuba sandstone	3rd Warren; Queen; 1st Bradford		1300	1210	1194		1030	795	985	960	965	1030	950			
			Canadaway			Clarenden; Sugar Run															
					Northeast	Speechley; Balltown, etc.	1275		1300			1190	1270	1150	1170		1195				1350
					Shumla sandstone	Tiona, Bradford 2nd			1420			1320				1250					1500
					Westfield	Sheffield; Harrisburg Run															
					Laona	Bradford 3rd; Richmond			1800				1470			1575		1650			
					Gowanda formation	Lewis Run; Bradford 4th										1675					
						Kane; Bradford 5th										1815					
						Smethport; Haskell										2025					
						Humphrey															
					Dunkirk																
		Portage	Chemung		Hanover												2650	2838	2500		
					to																
					Grimes sandstone												3563				
			Portage		Hatch												3575				
					to																
					Geneseo black shale											3855	4454	4653	4242	5427	
					Tully limestone	Tully limestone	6050	5580	4220	4151	3316	2800	1980	3780			4523	5042	4401	5523	5524
	Mid. Dev.		Hamilton		Moscow shale				4270		3322					4030	4529				5694
					to					4201									4483	5588	
					Marcellus black shale														5199	6162	
					Onondaga limestone	Onondaga limestone or chert	6750	6043	4500	4428	3478	2940	2160	4066	3760	4520	4963	5432	5405	6275	6168
	L.D.	VII VI			Oriskany sandstone	Oriskany sandstone	6950	6248	4720	4648	3612	3100	2450	4135	3889	4590		5439	5422	6280	6237
					Helderberg limestone			6353		4712	3763		2500	4138		4600	5045	5464	5472	6311	6261
SILURIAN	Niag. Cayu.	V			Keyser to	Unnamed	7060				3943	3285				4690	5350				6420
					McKenzie							4180				5540	6225				
					Clinton						5366	4440	3285		4995	5830	6545				
					Tuscarora sandstone	Medina (Albion of N.Y.)					5736	4685	3485		5155	6015	6721		9400?		
ORDOVICIAN	Cincin.	IV			Juniata						5834										
		III			Bald Eagle sandstone																
					Reedsville shale																
	Mohawk	II			Trenton limestone	Trenton							5200								
					Black River limestone																
					Lowville limestone																
					St. Peters sandstone	St. Peters							5960								

knowledge. Knowledge of the reserves differs widely because core analyses are abundant in one area and lacking in other areas. Where possible, figures obtained from core analyses in one area were applied to other areas geologically similar but lacking core data. In 1934, to meet a Congressional inquiry, a group of oil geologists and engineers estimated the oil reserves as of that date with some care. The Bradford field was treated by itself as abundant core analyses give a very accurate picture of that field. For the rest of the oil area, the group adopted 8 feet as the average thickness of productive sand, an average porosity of 13 percent, and an average original saturation of 60 percent. This gave an original oil content of 4,845 barrels per acre. The total area outside the Bradford field, based on planimeter measurements on the Survey's 1932 oil and gas map of Pennsylvania was estimated at 556,992 acres. Allowing 15 percent for barren areas within the oil pools reduced the area to 473,443 acres. The total production south of Bradford to that date was 578,290,000 barrels or 1,221 barrels per acre, leaving 3,624 barrels per acre in the ground. Experience shows that sand containing less than 150 barrels per acre-foot will yield no oil by any present known method. Therefore, 1,200 barrels should be subtracted as unobtainable, leaving 2,424 barrels per acre as the recoverable oil.

Since that date several quadrangles in northwestern Pennsylvania have been mapped in great detail and careful and detailed estimates by sands made for those areas. Also, a call for new estimates from the Office of the Petroleum Coordinator and Office of Price Administrator in Washington led Messrs. Dickey and Matteson to review carefully the whole oil field. The known oil fields were outlined on topographic quadrangle maps, divided into small areas of different sand thickness, depth, and oil content. The acreage of each of these small areas was measured by planimeter and its oil content estimated, using core data where available, or based on core data in similar areas elsewhere. Secondary recovery estimates were based on such detailed studies as were available. Where such data were not available, it was assumed that all oil over 150 barrels per acre-foot was obtainable by present known methods if cost were not a factor, but that at present prices not more than 40 percent of the oil over 150 barrels per acre-foot would be obtained commercially. Their figures, published in the Oil and Gas Journal for December 18, 1941, are summarized as follows: (minus the estimated acreage and volume of oil in the New York part of the Bradford pool).

OIL RESERVES OF PENNSYLVANIA

(Dickey and Matteson)

District	*Productive acreage*	*Total oil, bbls.*	*Economically recoverable oil, bbls.*
Bradford	84,000	976,000,000	67,352,000
Kane to Butler	347,770	2,074,500,000	215,400,000
Southwestern	112,870	631,000,000	75,000,000
Total	544,640	3,681,500,000	357,752,000
In New York	11,550	136,500,000	7,752,000
In Pennsylvania	533,090	3,545,000,000	350,000,000

To reduce these figures to a county basis in line with the rest of the report, it is necessary first to recompute the figures for the Pennsylvania part of the Bradford pool and to add the acreage and oil of the other pools in McKean County to obtain the figures for that county. McKean County figures are as follows:

RESERVES IN McKEAN COUNTY (Millions of barrels)

	Bradford pool			*Outside Bradford pool*	*Whole County*
	Whole.	*In N. Y.*	*In Pa.*		
Areas (square miles)	131	18	113	24	137
Oil after primary but before water-flood recovery	1,046	136	910	150	1,061
Recoverable by water flood	305	39	266	...	...
Water flood to June 1, 1942	186	18	168	...	...
Oil left January 1, 1942	118	20	98	...	...
Omit high cost oil	51	7	44	...	...
Practical oil reserves	67	13	54	11	65

These figures are based on Fettke (Pa. G.S. Bull M 21), brought up to date (Acres, Bradford pool: whole 84,000; N. Y. 11,550; Pa. 72,450). The available oil outside the Bradford pool is a crude estimate based on an assumed 720 barrels per acre recoverable oil. At an annual recovery of 13,000,000 barrels from the county, the oil at present prices would last 5 years. It will last longer because production will decline and doubtless much high cost oil will be produced. And remember that on January 1, 1944, the outlook for oil outside Pennsylvania was not too bright. When the country has to turn to oil shale and coal it should be possible to obtain profitably a large part of the oil still locked up in the oil sands, more than equalling all that has been obtained to date.

To shift the figures from a quadrangle to a county basis, the surface acreage of oil sands in each quadrangle was first divided into the parts of that acreage in each of the counties occurring in the quadrangle. These parts were then brought together to determine the areas in each county. To determine the quantity of oil in each county under the three headings in the table below, the number of barrels per acre for each column in each quadrangle was determined from tables by quadrangles published in the Oil and Gas Journal of December 18, 1941. The barrels per acre multiplied by the acreage of that quadrangle in that county were added to similar figures from other quadrangles that overlapped the county, and furnished the figures in the table below. These figures were generalized to bring them in accord with the figures in the preceding table, and are as of January 1, 1941.

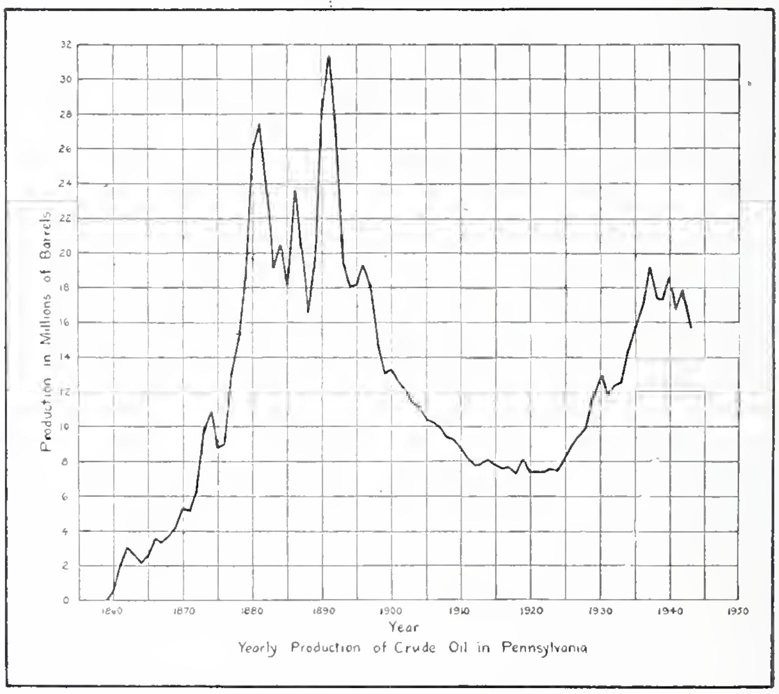


FIGURE 9. CURVE OF OIL PRODUCTION

Unknown oil reserves. It may seem foolish to attempt to compute the unknown oil reserves of Pennsylvania. To reduce those reserves to figures, would be. But it would be just as foolish to ignore the possibility that many pools are as yet undiscovered. The discovery of Music Mountain pool in 1937 with wells having a maximum initial open flow capacity of 600 barrels per hour, in the edge of the famous Bradford pool shows what may exist.

ESTIMATED OIL RESERVES OF PENNSYLVANIA, BY COUNTIES
(Thousands of bbls.)

	Area		*Total oil in the ground*	*Physically recoverable*	*Economically recoverable*
	Square miles	*Acres*			
Allegheny	75	47,400	280,000	165,000	33,850
Armstrong	12	7,500	45,000	17,500	5,000
Beaver	18	12,000	57,000	30,000	8,400
Butler	117	75,000	450,000	180,000	46,000
Clarion	47	30,000	180,000	75,000	20,000
Crawford	10	6,500	55,000	20,000	4,000
Elk	19	12,000	75,000	24,000	7,000
Forest	23	14,500	90,000	30,000	10,000
Greene	21	13,855	50,000	20,000	5,000
Jefferson	5	3,200	20,000	6,000	2,000
Lawrence	11	7,000	45,000	18,000	4,000
McKean	137	87,920	875,000	130,000	65,000
Mercer	9	6,000	36,000	15,000	4,000
Potter	2	1,000	6.000	2,000	650
Tioga		200	1,000	...	....
Venango	179	114,600	706.000	275,000	72,000
Warren	86	55,000	330,000	144,362	35,350
Washington	61	39,415	244.000	160,000	27,750
Totals	832	533,090	3,545,000	1,311.862	350,000

The principal oil pools of Pennsylvania lie in a belt 40 miles wide and 175 miles long on the east edge, containing about 5,280 square miles or, 3,380,000 acres. If ½ million acres were considered as proven oil-bearing and a million acres of this area as proven non-oil-bearing, there is still more than half the area to be classed as untested. To assume that the untested half would produce as much oil as the tested portion certainly is unwarranted. And there are good reasons for not having tested some of it. Nevertheless, it is certain that many millions of barrels lie underground undiscovered.

The fact that the oil in Pennsylvania was accumulated in stratigraphic traps not in relation to structure renders difficult the discovery of this oil. The Survey in cooperation with the United States Geological Survey has been experimenting with electric devices in the hope of finding a method that will indicate directly where oil underlies the surface. To the present these have not demonstrated their ability to reveal oil. It is, however, highly probable that a method or methods will be found. This would render available all of the now unknown reserves.

Recovery of oil by mining. Attempts to recover oil by mining are in progress. A shaft 429 feet deep has been sunk near Franklin. From a room at the base, radiating horizontal holes are being drilled in the sand. It is too early to tell how successful this attempt will be. Plans are being considered for an experimental mine with two shafts connected by a drift driven just below the oil sand. From such a drift, it may be possible to study the comparable effects of present methods of recovery and try out new methods. Such studies may not prove profitable at this time, but will point the way to ultimate recovery of all the oil possible.

Gas reserves. Gas reserves are in a quite different category from oil. The gas is highly mobile and when it ceases to flow by its own energy, can be pumped out by suction. When a gas field fails, it is ended. The question is, therefore, simply a matter of estimating the exhaustion of known fields and the discovery of new fields. True, gas wells, like oil wells, need to be kept clean and open. But that is assumed. The distance from which a well will draw gas is limited. Production is maintained principally by the drilling of new wells in known gas territory. Gas production in Pennsylvania in recent years is not far below its peak production. It reached 115 billion cubic feet in 1937. That it can continue long at so high a level is improbable. The piping of cheap gas from the South and Southwest will keep the price down as long as gas is plentiful in those areas. When gas from these sources plays out, doubtless the price will be raised to permit widespread wild catting. Undoubtedly there are many undiscovered gas pools. About all that can be said at present is that gas production in Pennsylvania may be expected to continue at or a little below the present level for ten or twenty years and then gradually decline during the next hundred years to extinction.

Drilling for Natural Gas
by Clarence McWilliams

This scene is typical of the rolling hills of the southwestern counties and the close pattern on which gas wells are drilled in some fields. The tall rig has a shieve wheel at the top over which the drill rope or cable passes. It is wound on a large reel at floor level. The small building covers the engine and the lower connecting structure protects the belt. The walking beam raises and lowers the drill tool.

The following table prepared originally by Stanley H. Cathcart for presentation to the American Institute of Mining and Metallurgical Engineers, has, in part, been brought up to date. The acreage figures were obtained by planimeter from a State Survey map:

DATA ON NATURAL GAS

(S. H. Cathcart, 1933)

County	*Acres Proven*	*Total production 1906 to end 1933 MM*	*Total 1942 M. Cu. Ft.*	*Producing oil and gas wells, end of 1933*				*Deepest zone tested, depth in feet **	*Depth of hole in feet **
				Oil only	*Oil and gas*	*Gas only*	*Total*		
Allegheny	11x,xxx	105,xxx	3,248,184	1,549	?	462	2,011	Salina	7,470
Armstrong	28x,xxx	167,xxx	15,639,688	261	?	2,144	2,405	Helderberg 6,663	6,889
Beaver	25,xxx	4,xxx	107,529	77x	?	30	80x	Queenston	6,822
Butler	6x,xxx	44,xxx	1,447,033	5,484	?	420	5,904	Medina 6,452	6,680
Cambria			10,172	....	...	?	?	Catskill, 800′ down	3,300
Clarion	181,xxx	149,xxx	8,513,165	2,387	?	3,9xx	6,2xx	Helderberg	5,737
Clearfield			95,183	....	...	?	?	Hamilton 7,050-	7,490
Crawford	1,xxx		....	8xx	?		8xx	Queenston	4,619
Elk	99,xxx	70,xxx	6,729,694	1xx	?	1,3xx	1,4xx	Queenston	7,930
Erie	3,xxx	5xx	40,248	....	...	53	53	St. Peter 5,179-	5,191
Fayette	11,xxx	30,xxx	6,159,576	....	?	178	178	Oriskany 8,590	8,685
Forest	19,xxx	13,xxx	885,117	....	1,491	...	1,491	Salina	5,252
Greene	25x,xxx	197,xxx	11,573,605	754	?	1,639	2,393	Oriskany 7,016-	7,118
Indiana	64,xxx	45,xxx	2,963,853	....	..	250	250	Hamilton	7,002
Jefferson	105,xxx	119,xxx	12,226,413	....	16x	2,28x	2,44x	Salina 7,494	8,227
Lawrence	8,xxx	1,6xx	17,466	7xx	?	15	7xx	Clinton	6,360
McKean	76,xxx	51,xxx	4,322,619	31,xxx	..	1,76x	32,76x	Queenston	5,820
Mercer	16,xxx	4,xxx	89,228	381	?	82	463	Queenston 5,481	5,485
Potter	35,xxx	24,xxx	4,575,312	251		1,031y	1,282	Queenston	8,482
Somerset	6xx	3,xxx	....	....	...	3	3	Up. Devonian	4,596
Tioga	7,000	24,913	482,719	52	...	41y	93	Vernon shale	7,148
Venango	44,xxx	56,xxx	2,578,390	24,428	?	85x	25,27x	Salina	5,055
Warren	4,473	11,xxx	547,087	6,388	147	164	6,699	Queenston	5,818
Washington	19x,xxx	155,xxx	7,353,463	1,746	?	911	2,657	Salina	7,248
Westmoreland	95,xxx	82,xxx	8,035,654	...	?	707	707	Oriskany 8,847	9,024
Totals	1,6xx,xxx	5,407,149w	97,641,398	80,548		16,460	97,008		

* From figures by Chas. R. Fettke.

w Total production 1882 to end 1933.

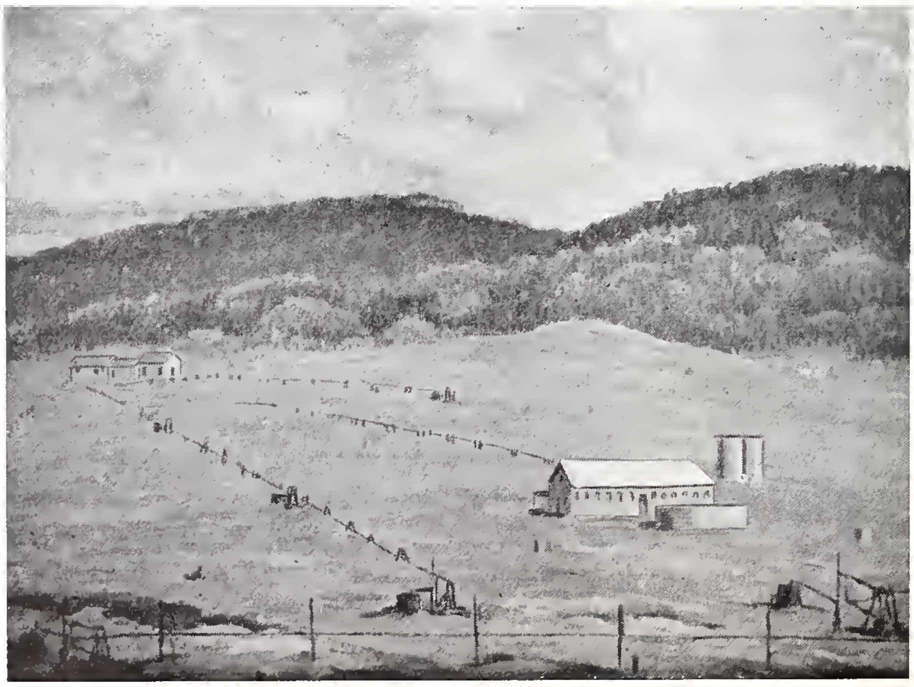
x Exact figures not at hand.

y Potter Co. deep gas nearing exhaustion. Tioga Co. gas exhausted.

z 1941. In 1942 gas production from shallow sands was increasing but decreasing from deep sands. From a production of 30,000 million cubic feet in 1939, by 1942 deep sand production had dropped to 2,500 million cubic feet.

This picture shows rod lines radiating from the power house at left, pumping jacks at three wells in foreground, field storage tanks and pressure plant.

The Pennsylvania Geological Survey has issued thirty reports on oil and gas. Ask for a list of publications.



Five-Spot Secondary Recovery of Petroleum by Christian J. Walter

METALLIC ORES

PRECIOUS METALS

GOLD AND SILVER

The precious metals, gold and silver, have never been produced in Pennsylvania in more than very small amounts except as a by-product of the production of magnetite at Cornwall, Lebanon County. Silver-bearing galena was mined at the Pequea Mine, in Lancaster County, before the Revolution and specimens of similar galena have been obtained from some other lead localities in the State. The Cornwall ore yields significant quantities of both gold and silver which are associated with chalcopyrite, an ore of copper.

The highly metamorphosed pre-Cambrian and early Paleozoic rocks of the Piedmont province in southeastern Pennsylvania are the only rocks genetically suited to contain the ores of the precious metals. The record of no production in this area and the nature of most of the mineralogy indicate the probable absence of these ores.

IRON AND FERRO-ALLOY METALS

The history of iron ore production and mining in Pennsylvania is well known.[1]

There are four classes of iron ore in Pennsylvania: hematite, brown hematite (bog ore and limonite), magnetite, and carbonate. These ores supplied more than half of the entire production of iron ore for the United States in 1850. Now less than two percent of this country's iron ore is produced in Pennsylvania. Whereas all four classes of ore were produced in 1850 and the brown ores were mined in greatest abundance, during the last decade magnetite from Cornwall was essentially the only ore mined. All four kinds of ore comprise the reserves for future use, with brown ores probably in the greatest abundance.

HEMATITE

Reddish hematite ore occurs chiefly in the Clinton formation of Silurian age. The Clinton ore ranges in thickness from a few inches to about three feet (rarely more) where it is known in outcrops in Snyder, Mifflin, Perry, Juniata, Blair, Huntingdon, Bedford, Columbia, Lycoming, Montour, Union, and a few other counties. Because of the stratigraphic position of the Clinton ores above the mountain-making Tuscarora sandstone, they are usually found near mountain slopes and the dip of the ore beds is usually steep. Because of the steep dip, large stripping operations are impracticable; and because of the combination of these undesirable features (especially the thinness of the ore), profitable mining has not been possible for the past 30 years.

The best figure on the total available quantity of these ores is 5,000,000 tons, estimated in 1909.[1] This ore constitutes a real future reserve. To mine the ore profitably will depend on a combination of cheaper labor costs, better mining technology, and different market conditions. Detailed structural mapping of the areas including the Clinton ore may possibly indicate certain localities where the ore bed is thicker. Such a study, with a certain amount of exploratory drilling, may indicate areas where the Clinton ore is relatively flat-lying and under thin enough cover to warrant stripping.

BOG ORE

Bog ore deposits are fairly common in all of the high plateau counties north and west of the Allegheny Front. Recent experience indicates that the presence of bogs, ranging in size from a few feet in diameter to more than one acre in area, are far more abundant than expected. The ore from these deposits has had two main markets in the past; the pigment and paint industry and the gas industry, in which the ore was used to remove sulphur from gases.

These deposits are located on large flat areas where swampy waters of the past have accumulated and dried up, on benches and terraces of many of the steep tributary valleys of the plateau country, on the narrow flood plains adjacent to many of the plateau streams, and at the foot (or toe) of many large talus slopes, especially in the northwestern counties. They range in thickness from several inches to ten feet. Their character is variable, some containing considerable sand, clay, and plant rootlets mixed with the ore, while others are relatively high-grade, under the top four to six inches. They range in color from light tan to deep maroon. Many of the bogs contain manganese oxide up to five percent.

Bog ore reserves in the plateau counties are probably of considerable magnitude. At least one bog discovered in 1941 contained more than 4,000 tons of ore. It is not likely that many are much larger.

LIMONITE

Residual deposits of brown limonite constituted Pennsylvania's chief source of iron ore for many years

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[1] Hickok, W. O., IV: Iron ores of Pennsylvania: Penna. Topog. and Geol. Survey Bull. M 18-B, 1939.
Second Pennsylvania Geological Survey Reports C-2; C-4; D-3, Vol. II; 1885 Annual Report.

[1] Papers on the conservation of mineral resources, U. S. Geol. Survey Bull. 394, p. 88, 1909.

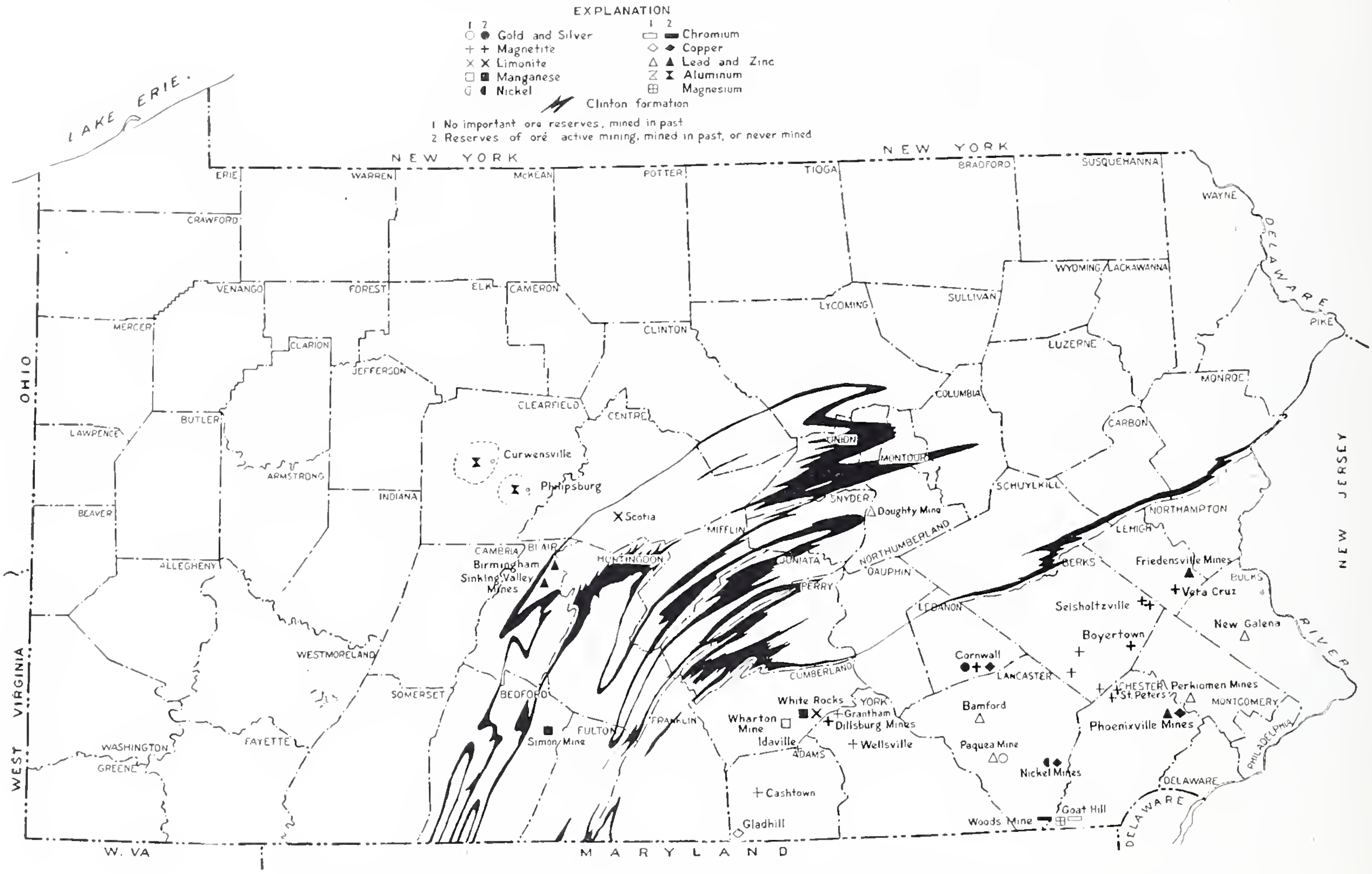

FIGURE 10. MAP SHOWING THE LOCATION OF METALLIC ORES

and were responsible at the time for the leading position this State occupied among the country's producers of iron ore. These deposits have been divided into two classes: valley ores and mountain ores. The valley ores appear as irregular, shallow pockets or as scattered lumps in clay, derived from the decomposition and solution of the Cambro-Ordovician limestones and dolomites. Most of the deposits, which are mixtures of hydrous iron oxides (limonite) and clay, lie within 50 feet of the surface and are soon exhausted.

The mountain ores are more variable in occurrence and appearance. They have been formed by leaching iron-rich shales, sandstones, or thin limestones or iron-carbonate beds, and are commonly elongated parallel to the strike of the rocks and confined to the surface zone of weathering.

Stratigraphically the brown ores are associated with rocks from pre-Cambrian to Carboniferous. Pre-Cambrian ores occur in the gneisses and schists of southeastern Pennsylvania in small, scattered deposits. They were worked in the early days but have little to offer for the future. The ores associated with the great Cambro-Ordovician limestones, which underlie the Chester, York, and Lancaster Valleys, the south half of the Kittatinny Valley, the Nittany and other smaller valleys, occur mainly at the contact of the limestone with the underlying quartzite (Chickies and Antietam), and in the lower Ordovician limestone series with a few scattered deposits elsewhere. The location of these horizons is shown on the State geologic map. Both horizons have yielded ore in the past and will doubtless be the principal sources of brown ore in the future.

Most of the old limonite workings probably exhausted their immediate supply of ore. Recent work [1] at the location of the Ege and Beltzhoover banks near Boiling Springs, Cumberland County; at the Scotia banks near State College, Centre County; and at the several other old iron ore open pits in Centre, Blair, and Huntingdon Counties indicates that large reserves of limonite ore remain. The ore lies deeper in some of the old pits and extends horizontally beyond the old working faces in others. When conditions are such that Pennsylvania brown ores can again be worked at a profit, the areas of former operation should be thoroughly investigated, especially by drilling. It is recommended that special attention be paid to the structural conditions attending the occurrence of the brown ores. In the case of the mountain ores, topographic and structural reentrants, causing synclinal deflections of the potentially ore-bearing horizons, may be very favorable locations for ore deposits. A large ore deposit of this kind was discovered near Boiling Springs, Cumberland County, in 1943.

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[1] Foose, R. M., The White Rocks manganese and iron ore deposits: Penna. Topog. and Geol. Survey Bull., in preparation, Nov. 1943.

Several "iron sandstones" of Silurian age have been the source of small amounts of ore. Unimportant ores occur in the lower Devonian. A carbonate ore in the Marcellus formation, weathered to limonite, has been extensively mined to a depth of 100 feet in central Pennsylvania where it is locally 15 to 20 feet thick. This ore may have large future value. Brown ores of Carboniferous age are confined mainly to the top of the Vanport limestone (buhrstone ore), resulting from the partial replacement of that limestone by waters bearing iron leached from the overlying shales. The ore is confined to the zone of weathering and, of course, to the counties containing the Vanport limestone, in general the lower Beaver and Allegheny River drainage area. The hilltops of western Pennsylvania have been benched for many miles by the working on this bed.

MAGNETITE

Magnetite for a great many years has constituted the bulk of Pennsylvania iron ore production. Although two types of deposits have been worked, only the Cornwall type is at present of commercial importance. It is of contact-metamorphic origin and Triassic age. The second type, of pre-Cambrian age, is associated chiefly with the granitic gneisses in South Mountain, Berks and Lehigh Counties, and rarely with the serpentine in the southeastern corner of the State.

Pre-Cambrian magnetite deposits. The magnetites of the pre-Cambrian rocks can be divided into two groups, according as they are associated with the igneous gneisses of the pre-Cambrian belt, stretching from south of Easton to Reading, or with the serpentine belt in the southeastern corner of the State. Small bodies of magnetite have been found in the serpentine, in serpentine quarries and chromite mines. This magnetite can be separated in mining and used for iron ore, but because of the scattered nature of the ore pockets, and their small size, it is doubtful if such mining will be found profitable.

Iron Ore Pit
by John Moffitt

This painting shows the end of the iron ore pit at Cornwall, Lebanon County, close to U. S. Route 322.

The South Mountain magnetites on the other hand will undoubtedly form part of the iron ore resources of the future. The deposits occur throughout the belt of pre-Cambrian rocks stretching eastward from Reading. In Pennsylvania the belt is about 60 miles long with a maximum width of 20 miles. The outcrop widens in New Jersey and the rocks contain several iron deposits which have been thoroughly studied by Bayley.[1] In Pennsylvania the deposits are smaller and never have been extensively developed. The ore is in several parallel veins or zones running east-west through the pre-Cambrian igneous gneisses, following the banding, locally cutting across it and even transgressing the boundary. Nowhere have magnetite veins been found in the sedimentary gneiss or marble of the pre-Cambrian.

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[1] Bayley, W. S., Iron mines and mining in New Jersey: New Jersey Geological Survey, vol. 7, pp. 89-193, 1910.

See also: Johnson, Meredith E., Iron Mining in New Jersey: Explosives Engineer, vol. 21, no. 6, November-December 1943, pp. 217-19, 242-3.

The ore is low grade; an average of all the analyses made of the ore from the Allentown quadrangle shows iron 42 percent, silica 35 percent, and small amounts of phosphorus, sulphur and manganese. The veins range in width up to 15 or 20 feet, generally being about 8 to 10 feet wide. They all descend at a fairly steep angle, making underground mining necessary. The ore is abundant; a small area near Vera Cruz is estimated to contain about 20,000,000 tons of low-grade ore above water level.

The Seisholtzville mines and the Rittenhouse Gap group of mines produced almost half a million tons. It is probable that considerable low-grade, concentrating ore remains in this area.

Cornwall type magnetite. The famous Cornwall magnetite body has been thoroughly studied,[1] as have others of the same type in Pennsylvania. Magnetite from Cornwall has been the only iron ore consistently produced in quantity in Pennsylvania since 1915. Reserves permit increased production on demand.

The Cornwall type of ore deposit is contact metamorphic, the ore being formed in all cases in a limestone host rock by mineralizing solutions emanating from an intrusive basic magma. The ore deposits are in the pre-Cambrian Franklin limestone (French Creek, Chester County)[2], Cambrian Tomstown dolomite (Boyertown, Berks County), Ordovician Conococheaque limestone (Cornwall, Lebanon County), and the Triassic limestone conglomerate (Dillsburg, Cumberland County). In every case the intrusive diabase is of Triassic age, and the ore of this type is, consequently, limited to the belt of Triassic rocks in southeastern Pennsylvania.

The entire Triassic belt has been investigated in a cursory manner by many parties, and some localities have been studied in considerable detail. Detailed examinations of the Dillsburg area and of some of the area between the large producing or former producing districts would be merited. The ore at Dillsburg is low-grade, but knowledge of its extent and continuity is meager.

The Boyertown area definitely contains magnetite reserves which will be mined in the future. Their extent is not clearly delineated, although Defense Plant Corporation sponsored diamond drilling in 1943-1944 may outline the limits of the ore body. There are a million tons of measured (proved) ore fairly near the old working faces; exploratory drilling may prove more.

Possible reserves in the French Creek district of Chester County, and at the Wheatfield, Fritz Island, Raudenbush, Jones, and Kinney deposits in Berks County are entirely dependent upon further exploration work to determine their magnitude. The reserves are not likely to be large.

CARBONATE ORES

Carbonate ores occur with the brown ores of the Cambro-Ordovician limestones in Pennsylvania, but are unimportant alone. The Marcellus carbonate ore, especially well developed in Carbon County, where the ore has been used in the paint industry, averages 1½ feet thick and constitutes small future reserves.

The best carbonate ore in the State probably is associated with the top 15 to 20 feet of the Mauch Chunk red shale, where it commonly occurs in 3 or 4 beds ranging up to 4 feet in thickness. The ore is mostly kidney-shaped and contains an average of about 35 to 37 percent of iron. These beds constitute minor reserves, although the continuity of the ore is not too well known.

Carbonate ores have also been mined from the Freeport limestone horizon in Allegheny, Indiana, Beaver, and Somerset Counties, from the Brush Creek and Ames limestone horizons, the Mercer horizon, from the strata associated with the Pittsburgh coal, and in some quantity locally from the Vanport horizon and that of the Johnstown cement bed. All of these horizons can still yield reserves of carbonate ore. Their character, however, makes these reserves of little significance for the near future.

MANGANESE

Manganese is the most important of the ferro-alloy metals. In the past there has been little production of manganese ore in Pennsylvania. A little more than 3,000 tons of both manganese and iron-bearing manganese ore were produced in this State up till 1943. The reason for this is partly due to the lack of proper exploration for and development of the ore. There are real reserves of manganese ore and of iron-bearing manganese ore that can be mined in the future.

With minor exceptions, oxides are the only manganese minerals found in Pennsylvania. An exhaustive examination of all the manganese mineral localities in the State through 1941-1942 [1], resulted in the listing of all the localities with regard to type and commercial importance, and the discovery of three important localities.

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[1] Spencer, A. C., Magnetite deposits of the Cornwall type in Pennsylvania: U. S. Geol. Survey Bull. 359, 1908.

Callahan, W. H., and Newhouse, W. H., A study of the magnetite orebody at Cornwall, Pennsylvania: Econ. Geol. vol. XXIV, pp. 403-411, 1929.

Hickok, W. O., IV. The iron ore deposits at Cornwall, Pennsylvania: Econ. Geol. vol. XXVIII, no. 3, pp. 192-255, 1933.

[2] Smith, L. L., Magnetite deposits of French Creek, Pennsylvania: Penna. Topog. and Geol. Survey Bull. M 14, 1931.

[1] Foose, Richard M., Manganese minerals of Pennsylvania: Topog and Geol. Survey Progress Report 128, 22 pp., 1942.

Reserves of manganese ore for potential future mining exist chiefly at three stratigraphic horizons. The Cambrian Tomstown dolomite along its entire northeast-southwest occurrence through southeastern Pennsylvania should be thoroughly investigated, especially at its contact with the underlying Antietam formation. The Cambrian Gatesburg dolomite through central Pennsylvania, and the basal beds of the Mauch Chunk formation, especially in the central part of the State, also merit careful examination.

The recent work on manganese ores in this State has probably not indicated all the locations where real ore deposits exist, but it has outlined the important features by which they may be found.

Insufficient exploration was conducted on the Mauch Chunk manganese ore in Sherman Valley, Bedford County, and further work would be merited to outline what are probably several "local" deposits of high-grade ore. Reserves of this ore are probably not large. Assuming moderate extension of the ore on the Simon property, 10 to 15 thousand tons of ore would be present.

Exploration of the White Rocks area three miles southeast of Boiling Springs, Cumberland County, during 1943 by U. S. Bureau of Mines with favorable results, clearly indicates the possibility of other localities with similar stratigraphic and structural conditions showing considerable manganese ore. At White Rocks the nodular manganese oxide deposit is located in the clay residually weathered from the Tomstown dolomite immediately overlying the Antietam quartzite. The ore body lies in a topographic and structural re-entrant along the northern flank of the South Mountain. The structure is that of half a synclinal basin open and plunging toward the northeast. Surface indications of ore along the flanks of the mountain at the general position of the Tomstown-Antietam contact are plentiful. There are numerous reentrants along South Mountain, most of which include the Tomstown and Antietam formations. These reentrants especially would be favorable places to prospect.

CHROMIUM

Chromite was produced in southern Lancaster County from 1828 to 1858, and from 1873 to 1882, at which time most of the mining ceased. The Wood mine, the largest and most famous, supplied nearly 100 percent of the world's chromite production prior to the Civil War. The ore was high grade, averaging 48 percent chromic oxide. Numerous smaller mines operated at the same time, and very small amounts of chromite have been produced from some of these smaller places since 1882.

The Wood mine was unwatered in 1937 and examined to its lowest level (about 720 feet); practically no ore remained. A drilling program by the Bureau of Mines and Geological Survey, U. S. Department of the Interior, in 1941 failed to find an extension in one direction of the Wood ore body or to outline any other ore body. This drilling should not be considered as indicating the absence of other chromite ore bodies in the serpentine rocks of southern Lancaster and Chester Counties. The pod-like character of all the ore bodies associated with the serpentine suggests the presence of others not yet found. It is thoroughly possible that there are deposits at depth which may be found by improved geophysical methods.

Placer chrome occurs along the streams that flow through the serpentine area. Small tonnages of this chrome constitute minor reserves. A great deal of material would have to be moved to obtain a small amount of chrome.

REFERENCES:

1. Frazer, Persifor, Jr., Geology of Lancaster County: Penna. Second Geol. Survey, Report CCC, 1880.
2. Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry—Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, p. 151, 1929.
3. Knopf, E. B., Chrome ores of southeastern Pennsylvania and Maryland: U. S. Geol. Survey Bull. 725, pp. 85-99, 1922.

NICKEL

Nickel ore was mined near Gap, in Lancaster County, from 1852 to 1860, and from 1862 to 1893. The ore was chiefly nickeliferous pyrrhotite. Prior to 1852, and sporadically from about 1740, the Gap mines were operated for copper, which continued to be an important by-product after the change to nickel was made. In 1877 the average annual production was about 7,200 short tons of ore.

The nickel-copper ores occur disseminated and in shoots in a large peridotite mass infolded in the metamorphic schistose rocks of the Mine Ridge complex. The ores that were mined may have included considerable violarite, a nickel ore mineral with more nickel than the nickeliferous pyrrhotite. The nickel content of the mined ores was about 2 to 3 percent.

It is probable that an unmined extension of lower grade ore remained in the peridotite adjoining the old workings. Other localities in the Mine Ridge complex that might be nickel-bearing are, of course, probably limited to areas of peridotitic rocks. There is at least one sulphide-bearing peridotite dike of considerable length that cuts through the complex. This especially, and several other finer-grained dikes, would merit careful geophysical examination. Several small areas of serpentinized peridotite, located about one mile west of the mines, also should be investigated.

REFERENCES:
1. Kemp, J. F., Trans. Am. Inst. Min. Eng. 21, pp. 622-631, 1894.
2. Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry—Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 141-150, 1929.
3. Frazer, Persifor, Jr., Geology of Lancaster County: Pennsylvania Second Geol. Survey Rept. CCC, pp. 163-176, 1880.

NONFERROUS METALS

COPPER

Copper is produced as a by-product of magnetite mining at Cornwall, Pennsylvania, and it was mined at the Gap Mine in Lancaster County from 1740 until 1893, the last 40 years as a by-product to nickel. Copper mining was attempted unsuccessfully in 1909 along South Mountain near the Maryland line in Adams County.[1]

The South Mountain copper is chiefly native and it occurs as small nuggets and as wires and grains in the greenstone (metabasalt). Associated with the native copper are small amounts of cuprite, and abundant thin films of malachite and azurite, especially along joint and other fracture planes. The largest concentrations of copper seem to have been found along sheared and brecciated zones and particularly at the contact of the greenstone with quartz-epidote rock. Although occasional lumps of native copper have been found, there was no apparent continuity to the ore.

Unless some method of geophysical prospecting could be satisfactorily used in this area, exploration would be too costly to be recommended on the basis of past results and the knowledge of the ores and their association.

Green and blue stains and films of copper carbonate are not uncommon in the Triassic shales, and in the Silurian and Devonian greenish shales of central and northern Pennsylvania. In no instance have these indications led to the discovery of ore at depth or in the vicinity. Very small veinlets of chalcocite have been observed in association with malachite (green film) in Sullivan County. These traces of copper minerals are superficial concentrations from overlying shales bearing minute percentages of copper.

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[1] Stose, G. W., Geology and mineral resources of Adams County: Penna. Topog. and Geol. Survey Bull. C 1, 1932.
U. S. Geol. Survey Bull. 430, pp. 122-131, 1910.
Biennial Rept. Topog. and Geol. Survey Commission of Pa. pp. 57-69, 1914.

MAGNESIUM

Magnesium has never been produced from Pennsylvania raw materials on a large scale.

The principal sources of magnesium are sea-water, magnesite and brucite, both of the latter two occurring only in small amounts associated with the serpentine rocks of southern Lancaster and Chester Counties. It is unlikely that much brucite will be found by further investigation of this area, although small pockets of magnesite may be revealed.

Recently dolomite has become a commercial source of magnesium. The introduction of dolomite as a raw material from which magnesium metal can be prepared entirely changes the picture of this State as a possible magnesium producer. Reference is made to the discussion of dolomite under the heading of Non-Metallic Mineral Resources and to The Limestones of Pennsylvania by B. L. Miller (Penna. Topog. and Geol. Survey Bull. M 20, 1934).

It is recommended that the widespread occurrence of dolomite in Pennsylvania be carefully investigated by magnesium producers. Although high-purity dolomite does not have large areal or stratigraphic extent in any single county or district, it is certain that fairly large reserves are available in Bucks, Montgomery, Chester, Lancaster, and York Counties.

OTHER REFERENCES:
Weitz, J. H., High-grade dolomite deposits in the United States: U. S. Bur. of Mines I. C. 7226, October 1942.
Schallis, Alvin, Economic considerations in the recovery of magnesia from dolomite: U. S. Bur. of Mines I. C. 7247, August 1943.

ALUMINUM

Until recently the production of metallic aluminum was almost entirely dependent upon bauxite reserves, of which Pennsylvania has none. As the result of experiments, dating mostly since 1941,[1] high-alumina clays averaging more than 35 percent alumina are now considered to be a potential, and probably a practical commercial, source of aluminum.

Flint clay of good grade contains an average of 38 to 39 percent of alumina. Nodular clays, associated with the flint clays, are chiefly diaspore, and they contain from 40 to 75 percent of alumina, dependent entirely on the amount of diaspore present. These two kinds of clay, both of which are highly refractory, are extensively mined by the various refractories companies [2] in Clearfield County and to a lesser extent in Centre, Clarion, Clinton, Jefferson, Cambria, and Lycoming Counties.

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[1] Independent laboratory investigations by Aluminum Co. of America, U. S. Bur. of Mines, and Tennessee Valley Authority.

[2] Harbison-Walker, General, and North American are the three largest companies.

Foose, R. M., The high-alumina clays of Pennsylvania: manuscript complete, but unpublished, March 1944.

Although a large percentage of all the clay in this large region is controlled by the operating refractories companies, there are many areas worthy of exploration which are not controlled by them. Of perhaps greater importance is the fact that refractory-grade clay must be low in iron content (less than three percent), and large quantities of high-iron clay are either dumped, gobbed, or side-tracked by selective mining. Large reserves of this material are probably available, especially in Clearfield County.

LEAD AND ZINC

The occurrence of lead and zinc ores in Pennsylvania has been described rather exhaustively,[1] and the possibilities of future production presented.

Active lead and zinc mining was limited to the large mines around Friedensville, Lehigh County and the Phoenixville mines, Chester County; and to the smaller mines in Blair, Bucks, Montgomery, Lancaster, and Northumberland Counties. The ore removed from the two larger districts was of good grade and amounted to fairly large tonnage. The smaller mines produced a good grade of ore, but the tonnage was small and mining conditions difficult in most cases.

The Friedensville district probably has large reserves of unmined zinc ore. It is well known that considerable ore remained at the time operations ceased and it is likely that considerable sulphide, silicate, and carbonate ore will be mined in the future.

The Phoenixville district may still have moderate reserves of unmined ore. The knowledge of the mining operations is scant in some respects and it is impossible to predict the reserves. It seems that a careful examination of this district would be merited and, if properly supervised, a certain amount of exploration work to determine possible extensions of ore from the old workings would be justified.

The Sinking Valley mines and the Birmingham mine in Blair County were last worked in 1870, and the opinion at that time was that the ores were exhausted. Some unfavorable prospecting has been done in these districts, which may bear out the statement concerning the lack of ore. It is not impossible that small reserves of ore will be found in the area. Detailed geophysical investigation of the district would be merited.

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[1] Miller, B. L., Lead and Zinc ores of Pennsylvania: Penna. Topog. and Geol. Survey Bull. M 5, 1924.

References:
Reports of the Second Pennsylvania Geological Survey on Blair, Bucks, Chester, Lancaster, and Lehigh Counties.

NONMETALLIC MINERALS AND ROCKS

BARITE

Barite or Heavy-Spar is a sulphate of barium, which when finely ground is used as an ingredient in certain paints, especially in place of white lead and as a filler and to form heavy muds in oil well drilling. It occurs as veins or masses in limestone, as nodules in clay, and as gangue with metallic minerals.

Barite as found in Franklin County is a massive to crystalline mineral, usually as lumps the size of a man's fist in clay residual from limestone, but also as thin veins. It was mined in the early 1880s and 1900s near Chambersburg, Mont Alto, and Waynesboro.

Barite was found many years ago near Fort Littleton, Fulton County, but was rendered worthless by the presence of iron. This mineral was mined long ago also near Buckmanville, Bucks County.

Only at the last locality is there evidence to warrant the conclusion that barite occurs in quantity sufficient to justify prospecting with the hope of discovering the ore in commercial quantity, and then only if the price of barite should increase materially. However, the lack of evidence in all cases is owing to lack of exposures. Trenches might uncover other deposits.

Reference: Pa. Geol. Survey Bulletin M 18 C, Non-metallic minerals, by R. W. Stone.

CLAY

It is believed that the first mineral industry in Pennsylvania was that of digging clay to make brick in the vicinity of Philadelphia. Today, clay production and clay-products industries are of great and widespread importance in the State. Since most of the clay mined is used by producers, no figures are available regarding the total quantity of raw clay produced.

Uses of clay. Although clay has many uses, it is difficult to make any statement regarding their relative importance as complete data are not available. Fire clay products, face brick, common brick, and pottery are the leading clay products, by value, manufactured in Pennsylvania, but clay is used for a great number of other clay products and considerable amounts are also used by other industries, as in portland cement manufacture, and for various uses outside of manufacturing.

Mining methods. Most types of clay are mined from open pits but fire clay is usually reached by drifts or shafts. Both methods of mining are used in Pennsylvania.

Areas of production. Few, if any, counties in the State do not produce or are not capable of producing some kind of clay, but special varieties of clay are more restricted in occurrence.

Fire clay. Fire clays are nearly pure hydrous aluminum silicates with very little of the fluxing elements such as iron, calcium, magnesium, sodium, or potassium. These clays fuse at high temperatures and are, therefore, suitable for lining furnaces and stoves either as plaster or in the form of bricks. Although such refractory uses lead, considerable quantities of fire clay are used also in the manufacture of sanitary ware, stoveware, high-grade tile, and other products. Such clays are produced in large quantities in the State. They constitute more than 80 percent of the clay mined and sold in Pennsylvania in some years.

Most fire clays are of the type called flint, block, or semi-flint, and the alumina content of these clays ranges from 33 to 40 percent. The refractory properties of the clay depend on the alumina content as well as the small amount of fluxing elements. Some of the fire clays, however, are nodular. The nodules are the mineral diaspore, and the greater alumina content of diaspore makes these clays very refractory and capable of use in preparing fire brick and cement which will withstand temperatures of more than 3300° F. These high-alumina clays are likewise a potential source of alumina and aluminum.

Fire clay is mined chiefly in the bituminous coal area in the counties adjoining the Allegheny Mountains, where it usually occurs underlying coal beds. The best fire clay (flint and nodule clay) is mined in the eastern and northern parts of the bituminous coal area; softer clays, used for fire brick not required to meet very high temperatures, are mined farther west in Beaver and Washington Counties.

Kaolin and white clays. Kaolin occurs in weathered pegmatites in the extreme southeastern part of the State. It used to be mined in Chester and Delaware Counties near the State line and particularly at Brandywine Summit, but production has long since ceased.

White clays are produced in Blair and Huntingdon Counties, principally for use in the steel mills of the Pittsburgh district; in the South Mountain of Cumberland County, chiefly for cement plants and for filler purposes; in Welsh Mountain of Lancaster County for use in steel mills and as filler; and in Monroe County for use in portland cement.

Clays and shales. Clays and shales suitable for making common brick have been produced in all but a few counties. Shale is used for much the same purposes as clay—for brick and tile manufacture and in cement manufacture.

Markets. Marketing is not a significant problem since most clay is used by producers. Some, however, is sold for use in other than mineral industries—to the paper industry as filler, to the rubber and paint industries—and some clay-products industries depend primarily upon purchased clay. In general, it may be said that nearly all low-grade clay products, such as common brick and sewer pipe, depend upon local clay. Higher-grade products, such as chinaware and porcelain, are of great enough value in proportion to their bulk to permit clay to be brought from considerable distance for their manufacture.

Reserves. Clay suitable for making brick occurs in every county, and clay and shale for face brick, sewer and drain tile is abundant in most of the counties. Fire clay is abundant in the bituminous coal fields. White clay for refractory purposes, white portland cement, and filler is much less abundant but probably other deposits than those mentioned can be discovered. Kaolin may be worked out at the old pits but investigation of other feldspar localities may discover undeveloped resources.

REFERENCES: Pennsylvania Geological Survey Bulletins:
M 10, Fire Clays of Pennsylvania, by J. B. Shaw.
M 17, Clay and Shale Resources of southwestern Pennsylvania, by Henry Leighton.
M 23, Clay and Shale Resources in Pennsylvania, by Henry Leighton.

DOLOMITE

Highly magnesian limestone or dolomite, carrying 40 percent or more of magnesium carbonate, occurs mostly in the southeastern part of the State, in Adams, Berks, Bucks, Chester, Lancaster, Lehigh, Montgomery, Northampton, and York Counties. It is reported also in Blair County, in the central part of the State.

The highest-grade material seems to be in Chester, Lancaster, and Montgomery Counties. This rock for many years has been crushed for road metal and concrete aggregate but since 1941 has been in demand for the production of refractory magnesia. Dead-burned dolomite is used also as a substitute for magnesite refractories in furnaces, converters, and crucibles for melting metals; it is the source of technical carbonate or basic magnesium carbonate that is used in the manufacture of pipe and boiler coverings and for general heat insulation, and of certain other commodities, including the acid liquor used in the sulphite process of making paper from wood. Since 1940 dolomite has been used to produce the metal magnesium; it is likely that future magnesium production from dolomite will increase. Some of the Pennsylvania dolomite is doubtless suitable for this purpose.

Dolomite is used extensively in Pennsylvania for making lime mortar and plaster, and in some other States for carbon dioxide, and in the manufacture of certain kinds of rubber goods.

Centuries of use have shown dolomite to be satisfactory as a building stone. It was so used by early settlers where it was the most readily available stone.

Deposits of dolomite in Pennsylvania are extensive, but high-grade dolomite is not as common. Deposits of dolomite are mostly in the Chester Valley, York Valley, and Cumberland-Lehigh Valley. Their occurrence, distribution and quantity are being investigated in 1943 by B. L. Miller for the State Geological Survey.

FELDSPAR

Feldspar is used in china and porcelain, in scouring soap, emery wheels, and certain kinds of glass and enamel. It is a constituent of granite and occurs abundantly in southeastern Pennsylvania, but the commercial occurrences are restricted to pegmatite dikes in southern Chester and in Delaware Counties. Thousands of tons of crude and ground feldspar were produced annually for use in pottery making until about 1920.

The output of feldspar in the first 20 years of this century was about 265,000 tons and brought the producers and local grinding mills nearly two million dollars. The average annual production in those years was about 13,000 tons and annual income about $100,000.

Pennsylvania produced 2,052 tons of crude feldspar valued at $8,551 in 1928, but that is the last year for which separate Pennsylvania figures are available. The industry dwindled until 1931 when only one quarry operated intermittently producing chicken grits, and then ceased.

The feldspar deposits are not exhausted and some of the deposits may contain as much unmined spar as has been taken from them. It is likely that other commercial bodies of spar remain undiscovered in this region and the possibility of renewing the industry should be considered.

References: Pa. Geol. Survey Bulletin M 13, Feldspar in Pennsylvania, by R. W. Stone and H. H. Hughes, 1931.
U. S. Geol. Survey Folio 223, Coatesville-West Chester.

GRANITE

Granite and related rocks are less important both in tonnage and value than trap rock in Pennsylvania. These relatively coarse-grained igneous rocks, including granite, various kinds of gneisses, schist and gabbro, are confined to the southeastern corner of the State. They occur in a belt extending from southern York County to southern Bucks County, and in irregular areas in northern Chester County, and in Berks, Lehigh, and Northampton Counties. Quarries in these rocks are numerous. Most of the quarries are producing rough building stone and the number of stone houses in some neighborhoods is notable. Mica schist and the various gneisses in the immediate vicinity of Philadelphia make excellent building stone, the durability of which is attested by small churches that were erected as early as 1715 and are still in use.

Swarthmore and Bryn Mawr Colleges and many other institutions near Philadelphia are built of the local granite gneiss, which differs from granite only in having a banded arrangement of minerals. Washington Memorial Chapel at Valley Forge is granite gneiss from Holmesburg, in Philadelphia, where a large quarry has been developed to a depth of 100 feet.

Many of the building-stone quarries are comparatively small and of intermittent operation, but some, like the Leiper quarry near Swarthmore, have been operated more than 100 years and have large dimensions. Crushed-stone quarries in these rocks range from small ones with portable machinery to completely electrified modern crushing plants capable of 3,000 tons daily output.

Granite for use largely in churches and schools is quarried in South Mountain between Reading and Allentown. Some of it has a reddish color, takes a high polish, and might be used for monuments except that the color is irregular in distribution. This feature is inconspicuous in rubble and rock-face ashlar.

The United States Bureau of Mines reported a Pennsylvania granite production for 1941 of 522,510 tons valued at $811,064. This includes trap rock sold as "black granite" monument stock, valued at $153,915.

About three-quarters of the granitic rock produced in 1941 was sold for concrete and road metal at an average value of $1.18 per ton. Gneiss and schist used extensively in the Philadelphia region as building stone amounted to 20,500 tons, valued at $47,712, or about $2.33 per ton. As gneiss and schist are the common bedrock in several hundred square miles, there is an abundance for all probable needs and uses.

References: Pa. Geol. Survey Bulletins: M 15, Building Stones; C 39, Lehigh County; C 48, Northampton County.
U. S. Geol. Survey Bulletin 799, McCalls Ferry-Quarryville Quadrangles; 891, Honeybrook-Phoenixville Quadrangles; Folios 162, Philadelphia; 223, Coatesville-West Chester.

GRAPHITE

Graphite is a soft, steel-gray or black mineral that, because of its very high fushion point, is used principally in making crucibles and other refractory products for the steel, brass, bronze, and electro-chemical industries. Other uses are in the manufacture of stove polish, foundry facings, lead pencils, paint for metallic surfaces, and lubricants.

The graphite deposits of Pennsylvania are limited to the greatly metamorphosed pre-Cambrian rocks of the southeastern corner of the State, mainly in graphitic gneisses and schists. All mines are in the Pickering gneiss.

Although graphite was prospected or mined some decades ago near Trevose and Langhorne, Bucks County, Pughtown, Chester County, Vera Cruz Station, Lehigh County, and extensively mined near Boyertown, Longswamp, and Mertztown, Berks County, the most important districts are in the valleys of French and Pickering Creeks in Chester County. In Pickering Valley, graphite has been mined in many places between Kimberton and Byers, a distance of eight miles.

The graphitic gneiss is extremely variable in mineralogical composition and texture, but in most of the mines it is so thoroughly decayed, even at the lowest levels, that crushing the rock is easy. The richer graphite-bearing beds may be sharply separated from barren rock but more frequently the change from ore to barren rock is gradual. Beds rich enough to warrant working vary in thickness from six feet to more than 100 feet. The amount of graphite in the workable beds ranges from 3 to 10 percent. Mining was mostly by open cut methods when the mines were operated intermittently between 1850 and 1920. The greatest recorded output was 2,271 tons in 1889. Production of 910 tons was reported for 1917-18, but this fell off to 242 tons in 1919 and no production has been reported since 1920.

After prospecting by trenches near Chester Springs, a modern mill was erected with Defense Plant Corporation funds and put into operation for a short period in the summer and fall of 1943. Flake graphite of various grades was produced for the Federal government.

Large tonnages of graphite are available in the Pickering Valley, but profitable production is dependent upon a financially stable mining operation on ore of good grade.

REFERENCES: Pa. Topog. and Geol. Survey Comm. Report No. 6, Graphite deposits of Pennsylvania, by B. L. Miller, 1912.

Pa. Geol. Survey Bull. M 18-C, Non-metallic minerals.

LIMESTONE

Limestone was one of the earliest materials utilized by the pioneer settlers, being used for building stone and burned for lime more than 200 years ago. The first statistics of production of limestone sold or used by the producers in Pennsylvania show a value of $2,655,477 for the output in 1890. This increased to $12,302,255 in 1918. In 1919 the quantity in short tons was first reported with the value. It was 10,665,500 short tons, valued at $12,640,411. Except in 1921-22, when there was a reported 30 percent slump in production, the output of limestone from 1920 to 1930 inclusive was around 12,000,000 tons per year, valued most years at more than $13,000,000.

During the depression years 1931-35 production was only about half of normal, but increased to a maximum of 17,319,520 tons valued at $17,752,691 in 1941, the latest year for which data are available. The value of limestone produced in Pennsylvania is greater than that of any other State, comparative values for competitors in 1941 being: Ohio $11,150,542, Illinois $10,639,662, and New York $8,985,614. These figures do not include the limestone burned for lime.

Limestone is widely distributed in the State, occurring in all the counties except 12 in the northeast and northwest corners. The southeastern third is particularly well supplied, with the Lancaster and Chester valleys producing large quantities of limestone, a lesser quantity of dolomite, and a small quantity of crushed marble. Many of the valleys of the Ridge and Valley section of the State are floored with limestone that is suitable for lime, fluxing stone, crushed stone, and other uses. The limestones of the southwest third of the State are not as abundant nor as high grade as those of southeastern Pennsylvania, but they are used locally to a considerable extent.

Mining methods. Limestone quarries are opened commonly in the side of a hill where tracks may be run into the quarry on a level terrace. Where the surface of the ground is level, it is necessary to sink a pit and haul the rock up a steep incline. Where the strata are steeply inclined, limestone may be mined by sinking a shaft, as at Bellefonte, and proceeding much as in the mining of anthracite where the dip is steep. In western Pennsylvania, where narrow, steep-walled valleys bring the flat-lying Vanport limestone to outcrop, drift mining is employed, similar to that used nearby in mining bituminous coal.

Uses. Deposits in Pennsylvania range from high-calcium limestone to high-magnesium dolomite and marble. The uses vary with the character of the rock.

The largest single use of limestone is in cement manufacture, but use for fluxing, and for concrete and road metal are of only a little less importance. Considerable quantities are burned for lime and used also in making glass, in agriculture, for railroad ballast, for rough construction work, by paper mills, and for sundry other purposes.

Value. The average value of the limestone produced in Pennsylvania in 1941 was about $1.02 per ton. Some uses have very exacting requirements and the limestone thus used is of relatively higher value, for instance, limestone for chemical lime and for glass manufacture and magnesium carbonate. For fluxing and some other large-scale uses the value per ton is less than $1.00, the average value of fluxing stone in 1941 being $0.89 per ton.

MARKETS

Since each use of limestone represents a market with definite location, limestone markets can best be discussed in terms of the major uses. The general statement may be made, however, that nearly all the limestone produced in Pennsylvania is used within the State.

Cement market. The largest user of limestone in Pennsylvania is the cement industry, located largely in the Lehigh Valley section. Most of the limestone required for this industry is quarried practically at the mill sites, and occurs in such large quantities that there is little likelihood of exhaustion in the near future. Indeed, the cement industry of the Lehigh Valley could be much extended if markets were available. A second important cement manufacturing region is in western Pennsylvania, particularly near Pittsburgh and in Lawrence and Butler Counties. Here the local Vanport limestone is used. It underlies many square miles and where close to the surface is quarried from huge pits, but where the cover is heavy is mined underground. Drift mining makes available enough stone for many years to come. Pennsylvania is entirely self-sufficient in the limestone required for cement manufacture, and should continue to be so.

Fluxing stone market. The second great use of limestone in Pennsylvania is for fluxing stone, used mainly by blast furnaces, but also in steel mills. The blast furnaces are located largely along the western border of the State, in the Pittsburgh district, and at Johnstown; but some are scattered along the great valley from Harrisburg to Bethlehem, and along the Schuylkill.

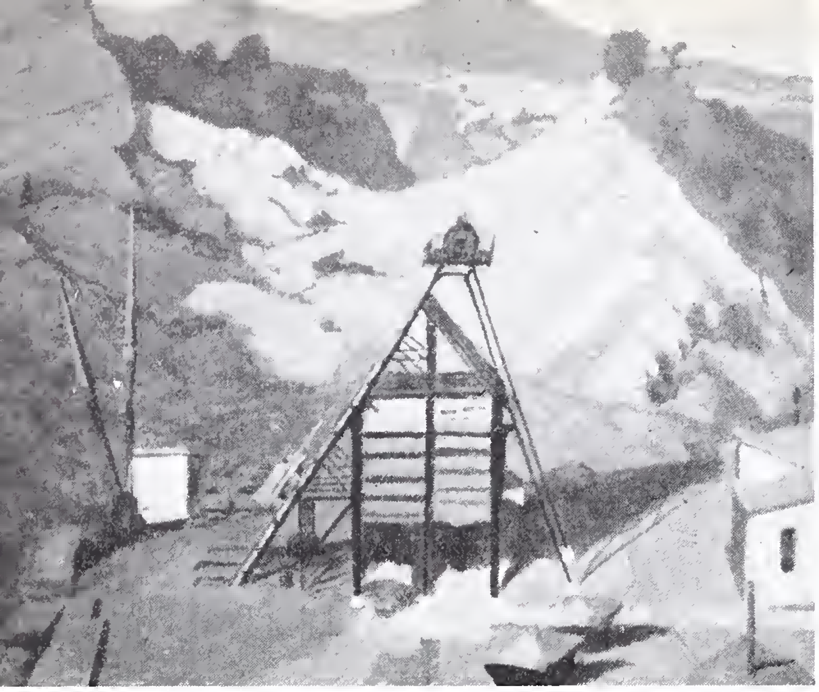
Limestone Quarry
by Saverio Di Magno

The choice of fluxing stone is governed by chemical requirements. Two types of limestone are in demand: low-silica, high-calcium limestone and low-silica dolomite. The matter of silica content is considered very important. For use as flux in blast furnaces, about 3 percent silica might be considered an upper limit. For open hearth furnaces, 1½ percent silica in the fluxing stone is rarely accepted, and about one-half of one percent is preferred. For making certain classes of steel the fluxing stone for use in bessemer blast furnaces should be as low in phosphorus as possible.

About 90 percent of the blast-furnace and open-hearth limestone used in western Pennsylvania and eastern Ohio is said to be obtained in western Pennsylvania. The limestone runs from 1 to 3 percent silica with a phosphorus content of .03 to .05 percent. Some Blair County limestone averages over 3 percent silica but has phosphorus as low as .005 to .01 percent. Some limestones in Centre and York Counties carry less than 1 percent silica, and have at times been shipped to the Pittsburgh district for open-hearth use.

Almost all the dolomite used for fluxing stone is for open-hearth furnaces. Pennsylvania dolomites within reasonable shipping distance of Pittsburgh are said to be undesirably high in silica. Hence the dolomite used in western Pennsylvania is obtained from West Virginia and Ohio. The iron and steel plants in the eastern part of the State obtain nearly all their fluxing limestone locally. It is an interesting fact that all the limestone used in the iron and steel industry of Sparrows Point, Maryland, comes from a quarry at Bittinger, Adams County, Pa., the most available source.

Notwithstanding the fact that Pennsylvania does not supply all the fluxing stone used in the State, the quantity of such material produced is large (more than 9,000,000 tons in 1941), and should continue so. Reserves seem to be adequate to supply the demand indefinitely.



Limestone Mine
by Robert Valentine

Concrete and road metal market. Wherever road construction or resurfacing is being done, concrete or road metal are used. Pennsylvania uses large quantities of limestone for these purposes, and has shipped it outside the State for road building. Crushed limestone goes into concrete for other types ot construction and finds a market chiefly in urban centers for buildings, bridges, and other structures.

Lime market. Limestone burned for chemical lime must be very pure; and the lime kilns commonly are located where such stone is quarried. Limestone of almost any quality is burned locally in kilns or in heaps for agricultural lime.

Building-stone market. Only a small quantity of Pennsylvania limestone is used for building stone, and that chiefly for rough construction. Much more might well be used for the rough stone bleaches to a light gray of pleasing appearance and is very durable. Limestone that could be used for building purposes is widely distributed and abundant in many counties except in the northern third of the State.

Reserves. Data are inadequate for computing reserves of dolomite and limestone in tons; rather it might be done in cubic miles. Leastwise the reserves may be said to be inexhaustable, except perhaps pure dolomite and high-calcium rock. When the construction of buildings and highways is resumed in the near future, as it must be to meet the demands, if the existing quarries are unable to supply the material on schedule, other quarries can be opened at points that will shorten the haul to large construction jobs remote from present quarries.

References: Pa. Geol. Survey Bull. M 20, Limestones of Pennsylvania, by B. L. Miller, 1934, 729 pp., 41 pls., 34 figs.
C 1, Adams County; C 39, Lehigh County; C 48, Northampton County; C 67, York County. All atlases.
U. S. Geol. Survey Bulls.: 840, Middletown Quadrangle; 855, Bellefonte Quadrangle; 891, Honeybrook and Phoenixville Quadrangles.

MARBLE

Marble has been quarried in the Chester Valley between Downingtown and Plymouth Meeting; in southern Chester County at Doe Run, Avondale, and Landenberg; and in York County. Founders Building at Girard College in Philadelphia was built of Pennsylvania marble in 1832. By the middle of the 19th century some quarries were extensive. Production first recorded in 1891 was valued at $45,000 increased to $267,000 in 1912, then decreased rapidly and ceased about 1921, except for rare subsequent small output. Marble is mined underground at Henderson for the production of whiting.

Most of the marble quarries are flooded, and outcrops are few. Should there be a renewed demand for production, ample quantities of various grades of marble can be found by following the strike of the beds exposed in the old quarries.

References: Pa. Geol. Survey Bulletin M 15, Building Stones.
U. S. Geol. Survey Bulletin 891, Honeybrook-Phoenixville Quadrangles; folio 223, Coatesville-West Chester Quadrangles.

MICA

Commercial muscovite mica was produced in very small quantities incidental to the mining of feldspar in Delaware and Chester Counties about 1900. There is no record of mining for mica alone.

Clear muscovite mica, free of magnetite and other impurities, occurs in many of the pegmatites of the southeastern counties, especially, Chester, Delaware, and part of Montgomery and Philadelphia. Unfortunately, in many cases, the clear muscovite is too intimately associated with mica of inferior quality to warrant its mining or separation.

The possibility of producing a good grade of sheet mica in dimensions more than three inches in diameter may be good. There are many unmined pegmatites in the area mentioned, besides those at the old feldspar mines. Half a mile south of Fairville, Chester County, just east of the main highway and adjoining an old feldspar open cut (filled with debris) is a favorable area with 4- to 7-inch blocks of quality mica and considerable quartz covering much of the ground. These may be the residual products from weathering of an underlying pegmatite.

In 1943, prospecting on the Walter property in the northern tip of Lancaster County, near its junction with Berks and Lebanon, resulted in the discovery of at least two pegmatites bearing mica of good quality and large size. The pegmatites range in width from

10 to 25 feet and the mica books up to 8 or 10 inches in diameter.

Localities like these could easily be prospected to determine the quality and size of the pegmatite. It is recommended that attention be given to the possible production of mica.

MICA SCHIST

Schist is a rock composed mostly of quartz and mica arranged in parallel laminae or layers; if in very thin layers and mostly mica it is called mica schist.

This rock is abundant in Philadelphia, Delaware, and southern Chester, Lancaster, and York Counties, and was used by some of the early settlers for building stone. That use has continued, and many houses built in the Philadelphia area in recent years are of this stone. The output from seven operations in 1941 was about 58,730 tons valued at $85,278. Sericitic schist or quartzite quarried at Edge Hill is used as a refractory lining of furnaces.

As mica schist is the common bedrock in several hundred square miles, there is an abundance for all possible needs.

References: Pa. Geol. Survey bulletins M 15, Building Stones; C 67, York County.
U. S. Geol. Survey bulletins: 799, McCalls Ferry-Quarryville Quadrangles; 891, Honeybrook-Phoenixville Quadrangles. Folios: 162, Philadelphia; 223, Coatesville-Chester; Prof. Paper 204, Hanover-York.

PHOSPHATE MINERALS

Several phosphate minerals occur in Pennsylvania, but wavellite is the only one that has been mined, and then only in two places. One locality is at Moores Mill, four miles west of Mount Holly Springs, Cumberland County, and the other between Blairs Mills and East Waterford, in Lack Township, Juniata County.

The Moores Mill deposit consists of nodules of wavellite in residual white clay near the contact of the Tomstown dolomite and Antietam sandstone. Wavellite is a hydrous aluminum phosphate. The mine was in active operation in 1905 and 400 tons of ore were reported to have been dug and reduced to phosphorus, used chiefly for making matches. Operations ceased about 1906, for what reason has not been learned. Wavellite was being taken from the old pit in 1943 for fertilizer experiments.

A few miles southwest of East Waterford drifts and crosscuts were driven many years ago in the impure rotten Oriskany sandstone where nodules of wavellite and amblygonite occur sporadically, but the deposit seems to be of no economic value as the phosphate minerals are not abaundant.

In the aggregate the two geologic horizons mentioned may contain large quantities of phosphate minerals but the material is so disseminated that, until someone demonstrates a large deposit, it is questioned whether it can be mined at a profit.

Reference: Pa. Geol. Survey bulletin M 18-C, Non-metallic minerals, by R. W. Stone.

SALT

Great stores of rock salt and brine lie beneath the surface of Pennsylvania, yet no salt is now produced in the State. The neighboring States of New York, Ohio, Michigan, and West Virginia are large producers of rock salt and of natural and artificial brine, so Pennsylvania is under no necessity of mining rock salt at a high cost.

Salt was made by evaporating weak brine from wells in the western part of the State for several decades in the nineteenth century, and up to about the time of the first World War salt was evaporated from brine obtained from deep wells on Allegheny River near Pittsburgh, but eventually the brine became too weak for profitable extraction of sodium chloride.

Salt water occurs at various depths in uncounted oil and gas wells in the western counties, and may be considered as a potential reserve, although it may be too weak or in insufficient quantity in some areas to be reduced to commercial salts at a profit.

Rock salt has been recorded in about 20 wells in 12 counties in the northern and western parts of the State. These are Beaver, Crawford, Elk, Erie, Forest, Jefferson, McKean, Mercer, Potter, Tioga, Warren, and Washington. The salt beds are in the Salina group in the upper part of the Silurian system, the same geologic formation from which salt is derived in the neighboring States. The salt beds were found in wells drilled for oil and gas. The thickness of salt reported ranges from 15 feet in Potter County to 130 feet in Beaver County and 145 feet in Tioga County, and the depth below the surface ranges from 2,300 feet near Lake Erie to 7,700 feet in Jefferson County.

The quantity of rock salt in a 10-foot bed under one county of 1,000 square miles would be equivalent to 2,700 times the quantity produced in the United States in a single year. There is evidence of the presence of rock salt under 12 counties whose aggregate area is 9,808 square miles, and it may underlie more than 20,000 square miles. It is assumed that the material reported by the drillers as rock salt is halite, although so far as learned no analyses have been made.

Considering the depth below the surface, it is presumed that this salt may not be used in the near future.

Reference: Pa. Geol. Survey bulletin M 18-C, Non-metallic minerals, by R. W. Stone.

SAND AND GRAVEL

Sand and gravel are a wide-spread and much used mineral resource. The reported production in 1941 was 10,515,940 tons, valued at $9,936,898. This industry thus ranked second (limestone first) in both tonnage and value among Pennsylvania's common rock products. Pennsylvania ranked eighth among the States in tonnage but third in total value of its sand and gravel production; this because the average value per ton was 94 cents, as against 56 cents per ton for California's much larger output, and 20 cents per ton for Minnesota's.

The uses of Pennsylvania sand include building, paving, glass, polishing, grinding, filtering, also for refractory purposes and traction. Gravel is used for building, paving, railroad ballast, and fill. By far the greater part of the sand and gravel produced is used for building; that is, in concrete, mortar, plaster, etc., and the second largest quantity for paving. Much of this large output is dredged on Delaware River and in the rivers near Pittsburgh. More sand is produced than gravel. Part of this sand is dug directly as sand, some is screened from gravel, and some, like glass sand, is obtained by quarrying and crushing sandstone.

Although sand and gravel are widely distributed, and are especially abundant in the glaciated regions, deposits for special uses are limited in occurrence.

Building and paving sand and gravel. Two outstanding sources of sand and gravel for building and paving are at opposite ends of the State. On the broad flat of Delaware River north of Philadelphia sand and gravel are dug by great dredges floating in artificial ponds. Dippers and bucket lines work to a depth of 30 to 40 feet below the surface. The material is thoroughly washed and screened and shipped both by rail and boat. Smaller operations using power shovels work in these same deposits above water level. North of Easton there are sand and gravel pits in glacial deposits along the Delaware and at a number of places in the northeastern counties.

In the west end of the State great quantities of sand and gravel are dredged from the bottom of the Ohio, Allegheny, and Monongahela Rivers in the vicinity of Pittsburgh, and at more remote places, as Point Marion in Fayette County. Some of the largest and most modern all-electric floating dredges in the country are operating in the Pittsburgh area.

Other sources of building and paving sand and gravel are along the upper Susquehanna River in Luzerne, Wyoming, and Lackawanna counties; along the West Branch of the Susquehanna in Lycoming County; and in the glaciated counties in the northwestern part of the State, as on the shore of Lake Erie, and on French Creek near Jamesville.

Since requirements for building and paving sand and gravel are not highly specialized, such bulky material is not, ordinarily, shipped for any considerable distance; but an exception to this rule is the shipment of sand and gravel to central Pennsylvania where such deposits are generally lacking. For instance, Harrisburg has used much sand and gravel from the Delaware River and from Chesapeake Bay. Extensive deposits have now been opened along the Susquehanna a few miles below Harrisburg.

The supply of sand and gravel along the rivers in the Philadelphia and Pittsburgh districts will last many years. Many counties in the northeastern and northwestern parts of the State are covered by a mantle of glacial deposits which constitute an inexhaustible supply for the more remote future.

Glass sand. The common kinds of glass, such as common tableware, bottle, plate, and window glass, contain from 65 to 75 percent silica. Although some sand with a minimum of 95 percent silica is used in the glass industry, the best glass sand is over 99 percent silica. Iron oxides are the most detrimental impurities of glass sand since they may cause green or yellow tints which reduce the brilliancy and transparency of the product.

Most glass sand produced is, in reality, friable sandstone, but, since it is crushed and used as sand, it is reported with sand and gravel and hence is discussed here. The quantity and value of glass sand produced in the leading States has not been published in recent years. This is to avoid revealing the output of any one company. Hundreds of thousands of tons of high-grade glass sand can be produced annually for many years to come by using the proper method of preparation. Should there be a greatly increased use of glass building blocks and other structural items, there may well be a renewed demand for the silica sand in the western counties.

The principal productive area is confined to the outcrop of the Oriskany sandstone in several localities in Huntingdon and Mifflin Counties, in the vicinity of Mapleton, Vineyard, and Granville along the main line of the Pennsylvania Railroad, between Huntingdon and Lewistown. In the western part of the State the workable deposits are distributed over a much greater area, but the quality of the sandstone available is not as good as that of central Pennsylvania. In this region glass sand quarries have been operated in Elk, Fayette, Forest, Jefferson, Venango, Warren, and Westmoreland Counties, all in the Pottsville sandstone.

Molding sand. In 1941 the State's reported yield of molding sand was 433,853 tons, valued at $669,450. Molding sand, which is used in casting metals, is of two kinds, natural bonded and unbonded. Natural bonded molding sand is a mixture of sand and loam that will hold its shape when compressed in a moist condition. Unbonded molding sand is silica sand that is used because of its highly refractory quality for casting steel. A mineral or organic bonding material is added as required. Natural bonded molding sand is dug in considerable quantity on Delaware River above Philadelphia, in smaller quantities along the Susquehanna at Cattawissa, Danville, and Washingtonboro, along the shore of Lake Erie, and in several other places. The unconsolidated deposits lying just below the sod are dug mostly by pick and shovel and loaded in trucks for hauling to railroad cars.

Silica sand. Silica sand of high grade is used for grinding and polishing, for molding steel, for refractory purposes, and for filter and traction sand. It is produced largely in Elk, Jefferson, Venango, Westmoreland, and other counties in the western end of the State by quarrying and grinding the siliceous sandstones at the base of the Coal Measures. There is no limit to the quantity available.

REFERENCES:

Pa. Topog. and Geol. Survey Comm. Report XII, Glass Manufacture and the Glass Sand Industry, by Chas. R. Fettke, 1919.

Pa. Geol. Survey Bulletin M 11, Molding Sands of Pennsylvania, by R. W. Stone, 1928.

SANDSTONE

The sandstone industry in Pennsylvania in 1941 included the production of 10,700 tons of rough building stone; 6,290 tons of rubble, a little curbing, 103,910 cubic feet of flagging; or approximately 26,030 tons valued at $120,961. Also 697,520 tons of ganister, more than a million tons of crushed stone for concrete and road metal; small amounts for riprap, railroad ballast, and other uses; in all, 2,093,130 tons of crushed sandstone valued at $2,600,267. The principal uses by far are as crushed stone for concrete and road metal, and as refractory stone or ganister.

The average value of sandstone for rough building in 1941 was nearly $2.50 per ton, curbing was just under $1, and flagging about 76 cents per cubic foot. Ganister averaged about $1.75 per ton, riprap about 40 cents, road metal and concrete stone just over $1, and all crushed sandstone averaged $1.24 a ton.

Varieties of Pennsylvania Sandstone.

Sandstone as here used includes bluestone and ganister as well as ordinary sandstone.

Bluestone. Bluestone is a variety of sandstone which occurs in northeastern Pennsylvania and in New York, and, because of the character of its bedding, is quarried for flagging and curbing. About 103,910 cubic feet of this stone (included in sandstone totals above) were quarried in Pennsylvania in 1941, valued at $79,564. This was about 1 percent by tonnage and 3 percent by value of the total sandstone production of the State. Pennsylvania ranked second to New York in bluestone production, the latter's production being 420,260 cubic feet valued at $119,629.

The bluestone quarrying industry is located in the northeastern corner of the State in Susquehanna, Wayne, and adjacent counties. Methods of quarrying are somewhat obsolete. Most of the drilling is still done by hand, and wedges are used to spring the holes.

Though an industry of long standing, bluestone quarrying was for a time greatly reduced by the increasing use of portland-cement concrete. During some recent years, however, there has been a revival in demand for natural stone, and this has stimulated the industry.

The heavy stock is used for ashlar, sills, platforms and other places having transverse strain; common flags are sold for walks and floors, both interior and exterior, in large institutions, public buildings, and private estates, and the very thin flags are now made into roofing shingles, wall panels, and tile to be set in cement. Flagging is also used for base-boards. Broken or irregular slabs, formerly waste, now are sold by the ton for garden paths.

One mill, at Meshoppen, Wyoming County, furnishes flags with natural or rubbed surface, in a variety of tons of red, blue, green and gray, and in any size from tile 1 foot square to flags for stair landings 7 feet by 9 feet and finished on both sides.

Ganister. The broken blocks of sandstone and quartzite that form the lower slopes of many mountain sides in Pennsylvania are referred to as "ganister." This material consists almost entirely of grains of quartz.

Though long unused, ganister now forms the basis for a considerable industry. It is used in making silica

Burning Silica Brick
by Christian J. Walker

brick for metallurgical furnaces, lime and cement kilns, and coke ovens, where a highly heat-resistant material is needed.

Methods of production are particularly simple on the lower mountain slopes. Because the rock on these floes is broken and loose the principal requirement for collecting it is a light railroad. As the floes lie at a high angle, a light track with switch-backs makes all parts accessible and the rock up to 2-man size can be loaded by hand. Some of the larger blocks may be broken by explosives before loading. The whole operation is one of stripping the surface of the suitable rock by hand selection and loading. When one area is stripped the track may be moved to another floe or, if the distance is too great, the ledge from which the stone was broken by nature's forces may become the site of a quarry.

A schistose quartzite quarried in Montgomery County is used, like ganister, for refractory purposes. It may be used in thin slabs for hearth lining, or may be crushed.

Other Sandstone and Quartzite. Other sandstone and quartzite quarries are scattered widely over the State and produce stone for a variety of purposes.

Building stone sold as rubble, riprap and cut stone has been produced in largest quantity at Koppel and Wurtemburg near Ellwood City in Beaver County, Neshannock Falls in Lawrence County, and Curwensville, Clearfield County. These quarries furnish a gray to tan or buff sandstone in blocks of any desired size up to those weighing 2 or 3 tons each for bridge masonry. The output of these quarries north of Pittsburgh is shipped as far east as Philadelphia. The Homewood sandstone of the Pottsville formation is the geologic horizon most used. Large quantities of curbstone have been made at Koppel and Wurtemburg for the Pittsburgh district. Curbing is cut also from the Connoquenessing sandstone at Madera, Clearfield County, and from the red Chemung sandstone on Lehigh River near White Haven, Luzerne County.

Red Triassic sandstone or brownstone is no longer quarried extensively for building stone in this State, the large operation near Hummelstown having been discontinued in 1928 for lack of demand. Lighter-colored stone is preferred.

Sandstone and quartzite rubble for building purposes is produced in other parts of the State but only in small quarries. Some very attractive and durable stone that dresses well to ashlar of variegated color is taken from fields of float on Kittatinny and other mountains without quarrying.

Some of the quartzites of central Pennsylvania are popular locally for building purposes. The Tuscarora quartzite, for example, has a white to pinkish color which is particularly agreeable, and it is an exceedingly durable stone. Quartzite is difficult to work, which handicaps it in competition with the other building stones. The use of the Tuscarora quartzite is now principally local, but the quantity of this stone available is great, and it would seem that the possibilities of extending its markets as a building stone should be worth investigation.

REFERENCES: Pa. Geol. Survey bulletins: M 3, Silica refractories of Pennsylvania, by E. S. Moore and T. G. Taylor, 1924; M 15, Building Stones of Pennsylvania, by R. W. Stone, 1932.

SERPENTINE AND TALC

Serpentine, a greenish rock, occurs in Delaware County, near West Chester, and along the State line in Chester and Lancaster Counties. It was formerly used for building stone. It is durable and retains its fresh color in the country, but in a city or where the air is polluted with acids, serpentine is likely to change color and to disintegrate.

A fine grade of serpentine suitable for panels was formerly quarried and polished at Easton. Talc in different grades of fineness has been produced for many years by grinding intermingled talc and amorphous serpentine from a quarry near Easton.

Statistics of production for the State are not available. Serpentine was quarried for building stone mostly in the latter half of the 19th century. Very little has been quarried for building in recent years. Several square miles of serpentine along the State line may be a source of magnesium and its salts.

REFERENCES: Pa. Geol. Survey Bulletin M 15, Building Stones of Pennsylvania, by Ralph W. Stone, 316 pages, 4 plates, 164 figures, 1932.
Pa. Topog. and Geol. Survey Comm. Report No. 5, Talc and Serpentine of Northampton County, by Frederick B. Peck, 1911.
Pa. Geol. Survey Bulletin C 48, Northampton County, Geology and Geography, by B. L. Miller, 496 pp., 29 pls., 36 figs., including geologic map, 1939.

SLATE

Quarrying of slate as a business in Pennsylvania probably began in the Peach Bottom district near the Maryland line about 1785 and in Lehigh County north of Allentown about 1828. By 1855 the industry was growing vigorously. For many years the Lehigh-Northampton district has been the leading producer in the country. Peach Bottom, the only other important district, was long a great producer of roofing slate, but operations ceased there about 1925, except for one quarry whose product is crushed for granules.

The tonnage of slate quarried each year in Pennsylvania is small when compared with tonnages of limestone and of sand and gravel; slate totals only a fraction of one percent of the common rock products. It is, therefore, less important on the basis of weight than of most other rock materials. In total value, slate ranks third among the common rock materials; and Pennsylvania ranks first in the country as a producer of slate, with an output of nearly 46 percent (by value) of the United States total, and more than 65 percent of the roofing slate produced in 1941. Vermont is Pennsylvania's closest rival, producing 25 percent of the country's total value in slate and 22 percent of the roofing slate.

Location. Pennsylvania has three slate districts: one borders on Maryland in Lancaster and York Counties and is part of the Peach Bottom district; another centers around Slatington and Danielsville and is mostly in Lehigh County; and the third lies wholly in Northampton County, centering around Pen Argyl, Bangor, Bath, and Nazareth.

Methods of mining. As a rule, slate is quarried by sinking deep pits, which in some cases are more than 500 feet deep. Very little slate is mined by underground methods. Slate quarrying gives rise to large cumbersome piles of waste rock. Many quarrymen store this waste in old abandoned pits.

During recent years the slate industry has made rapid strides in improving the technique of quarrying and manufacture, especially in the substitution of wire saws for channeling machines in making the primary cuts in quarries. This method is said to reduce waste and production costs, and save time.

Uses of slate. The largest use made of slate is for roofing, and the second largest use is for structural and sanitary purposes. Under this heading is included slate used for toilet appliances, shower stalls, sinks, tubs, grave vaults, vats, shelving, coping, hearths, billiard tables, stairs, tables, and lithographic stone. About half as great in tonnage as the slate used for structural and sanitary purposes was that used for blackboards and bulletin boards. Still smaller in quantity was slate used for electrical switchboards. This highly specialized use requires slate low in carbon and iron-bearing minerals.

Slate may be crushed to a granulated form and used in the manufacture of composition roofing. Slate in a pulverized form known as slate flour is used as a filler in paints, road-asphalt surface mixtures, roofing mastic, and various other products. All of the slate produced in the Peach Bottom district of Pennsylvania is granulated and powdered, except a small output of roofing slate; at the present time none of the slate produced in Lehigh and Northampton Counties is marketed in this form.

Value. Slate is the most valuable common rock product produced in Pennsylvania. Its high value and rather limited occurrence on the earth's surface almost exclude it from the group of common rocks. The value of slate varies considerably, depending on the use for which it is adapted. Slate in the form of blackboards and bulletin boards has the highest value, about $89 per ton in 1941, followed by electrical slate at $81, structural and sanitary slate at $45, and roofing slate at $22.60 per ton. Slate sold as granules and flour is at the lower end of the scale with a value of about $7 per ton. The average value of all slate is about $12 per ton, because the quantity of roofing slate so greatly exceeds blackboards and other dimension slate, and because the tonnage sold as granules and flour is so much greater than dimension slate. These values are the average for the nine producing States in 1941.

Market. Because slate is heavy and must pay rather high freight rates, more than half of the dimension slate is sold in States east of Ohio and north of Virginia. Five of the States of this group produce 90 percent of the country's slate. Many other commodities compete with slate in its various uses, but as long as slate is in demand, it is believed that suitable material can be produced in quantity by opening new pits, most of which presumably will be in Lehigh and Northampton Counties. The outcrops of the principal slate belts are by no means fully developed and some of the present quarries may go deeper. The deepest quarry at present is a little more than 800 feet; slate to supply the whole country lies at less depth and only awaits a market.

REFERENCES: Pa. Geol. Survey Bull. M 16, Slate in Pennsylvania, by Charles H. Behre, Jr. 400 pp., 5 colored geologic maps, 65 other plates, 89 figures, 1933.

Bull. 39, Lehigh County, Geology and Geography, by B. L. Miller, 1942.

TRAP ROCK

The material classed as trap rock in Pennsylvania is hard, fine-grained diabase, frequently called "black granite." It occurs in large and small irregular, detached areas in a belt extending across the southeast part of the State from Delaware River near Kintnersville to the Maryland line near Gettysburg. It crops out principally in Adams and northern York Counties, the southern parts of Dauphin, Lebanon, and Berks, and northern Montgomery and Bucks Counties. Many lesser bodies, chiefly long narrow dikes, occur in the southern parts of York, Lancaster, and Chester Counties.

This hard black rock meets all the requirements of the Pennsylvania Department of Highways and is used extensively for road metal; also for aggregate in concrete for general building purposes. Single quarries near Birdsboro and Quakertown have production capacity of 3,000 tons of crushed trap rock daily. This stone also makes excellent paving blocks. Although it is durable and can be dressed to ashlar, it is little used for building stone because the color is so dark that it makes a somber building.

Lighter colored (red and green) rocks sometimes classed with trap rock, but really altered lavas, occurring in South Mountain, Adams County, are extensively quarried and mined for the purpose of making roofing granules.

Trap rock and related rocks quarried in Pennsylvania in 1941 are reported by the United States Bureau of Mines to have had a tonnage of 1,326,820 and a value of $1,290,455. More than one million tons of the State's total production by weight was used in concrete and as road metal; railroad ballast, the second use in importance, accounted for about one-sixth of the total. In terms of value, the average for all stone included here was 97 cents per ton, and for crushed trap for concrete and road metal was 95 cents. These figures do not include 16,470 cubic feet of dressed monumental granite valued at $153,915, which presumably was trap rock.

"Black granite" for monuments. Three quarries in southeastern Pennsylvania are being worked for "black granite" monument stock. This material is trap rock, but because of its trade name it is classified with granite by the United States Bureau of Mines. "Black granite" is quarried at Coopersburg and Saint Peters and polished for monument stock. The highly polished black surfaces of this fine-grained stone show carving well and are highly resistant to weathering. This polished stone is suitable for exterior and interior paneling in office buildings, banks, and stores. The Shakespeare Memorial in front of the Free Public Library in Logan Circle, Philadelphia, is made of this "black granite" or trap rock.

An immense quantity of trap rock suitable for crushing is available in a belt more than 100 miles long, and it is possible that fine-grained "black granite" for monuments is abundant at other places besides where quarried now.

REFERENCES: Pa. Geol. Survey bulletins: C 1, Adams County; C 67, York County; A 168, Lancaster Quadrangle; A 178, New Holland Quadrangle; M 15, Building Stones.

U. S. Geol. Survey bulletins: 799, McCalls Ferry-Quarryville Quadrangles; 828, Quakertown-Doylestown district; 840, Middletown Quadrangle; 891, Honeybrook-Phoenixville Quadrangles. Folio 225, Fairfield-Gettysburg Quadrangles.

INDUSTRIAL GROUND-WATER SUPPLIES

JACK B. GRAHAM, *U. S. Geological Survey*

In recent years, the use of ground water, particularly by industries, has greatly increased. Clear, cold water finds many uses in present day industrial processes, and the clarity and cool temperature of most ground-water supplies make this resource one of the most important in planning for and maintaining certain industries.

In the past, consideration of the source, quality and quantity of water available has been too often an afterthought in choosing industrial sites. Water has been taken too much for granted and the attitude of many has been that if cheap sources of good surface water fail, it would be a simple matter to pump the required quantity from the ground. Fortunately, the true importance of water supply is now being recognized and information as to the quality, quantity, and dependability of sources is sought by scientific methods. A systematic investigation of the ground-water resources of the State has been undertaken by the Pennsylvania Topographic and Geologic Survey in cooperation with the federal Geological Survey. Six reports, each dealing with a section of the State, and a summary volume which reviews the data of the ground-water supply of the entire State, have been published. These reports are listed as Bulletins W 1-7, Pennsylvania Geological Survey, 4th Series.

The accompanying map indicates in a generalized way several gradations in the average productivity of ground water of rocks in Pennsylvania. It is obvious that a map of the size shown can indicate only broad divisions of ground-water yield, since it is recognized that wide variations frequently occur in the yield of wells in the same locality, and producing from the same formation. The water-yielding char-

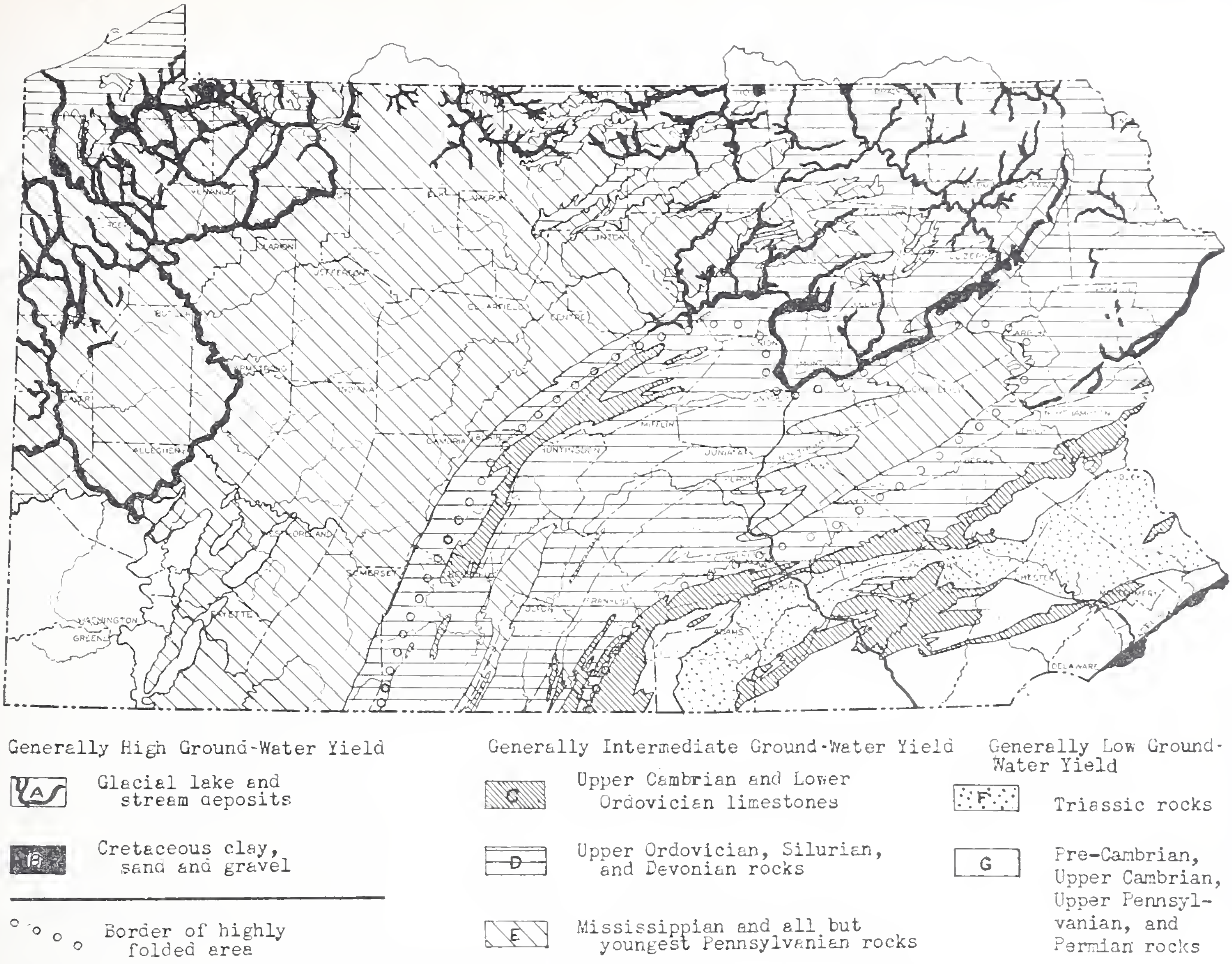

Generally High Ground-Water Yield
A Glacial lake and stream deposits
B Cretaceous clay, sand and gravel
Border of highly folded area
Generally Intermediate Ground-Water Yield
C Upper Cambrian and Lower Ordovician limestones
D Upper Ordovician, Silurian, and Devonian rocks
E Mississippian and all but youngest Pennsylvanian rocks
Generally Low Ground-Water Yield
F Triassic rocks
G Pre-Cambrian, Upper Cambrian, Upper Pennsylvanian, and Permian rocks

FIGURE 11. MAP SHOWING AREAS OF HIGH, INTERMEDIATE, AND LOW GROUND-WATER YIELD

acteristics of the various groups of rocks comprising each symbol shown on the map will be discussed briefly in the following paragraphs:

Glacial lake and stream deposits. The most productive water-bearing deposits in the State are the glacial lake and stream deposits formed by waters from the three great ice sheets that invaded Pennsylvania from the north during the Pleistocene epoch. These clay, sand, and gravel deposits are largely confined to existing or former stream valleys. (Symbol A of map.) In some places these sediments are 200 to nearly 500 feet thick. Where sand and gravel predominate, large yields, up to several thousand gallons a minute, may be developed. Water from these sediments is generally of good quality in northeastern Pennsylvania, but in the north central and northwestern areas of the State, the water may be hard and iron-bearing.

The restricted distribution of these deposits makes their exploitation similarly restricted, but in the localities where they occur, they present the most favorable conditions in the State for large ground-water yields.

Cretaceous coastal plain sediments. Sands and gravels of Cretaceous age, which are part of the unconsolidated coastal plain sediments of the eastern Atlantic coast, occur in a very limited area bordering the Delaware River in the extreme southeastern part of the State. These deposits, along with the glacial lake and stream deposits described above, are considered generally favorable for high ground-water yield. They are represented by symbol B on the map. These sands and gravels are important in supplying large quantities of ground water in some industrial areas of Philadelphia. The area of these sediments on the Pennsylvania side of the Delaware is small, and ground-water production has been heavy, particularly in south Philadelphia, so that continued development of this area as a ground-water supply may soon reach or exceed the recharge supply. Large wells may yield a thousand or more gallons a minute.

The water varies greatly as to hardness and iron content. Some of the shallow wells near the Delaware River or mouth of the Schuylkill may be deriving part of their water from these surface sources.

Upper Cambrian and lower Ordovician limestone. Three groups of rocks are shown on the map as being generally intermediate in their ground-water yields. Of these, the group that is the most favorable for large yields is shown by symbol C, which includes the limestones of upper Cambrian and lower Ordovician age. These rocks constitute practically a single lithologic unit with an aggregate thickness of 6,500 to 11,000 feet.

These limestones are hard and brittle, and are generally jointed and fractured, especially in the areas of highly folded rocks (see map). Solution channels have been formed along these fractures by percolating water charged with carbon dioxide, and it is due to this condition that these rocks frequently yield large quantities of ground water. If a well does not encounter one or more of these channels, there will be little or no yield. However, limestones in the area mapped generally have numerous openings, and dry holes are not common. The occurrence, size, and depth of such openings cannot be determined from the surface by geological methods. If no openings are encountered in a well, a new location perhaps a few feet removed from the dry hole may yield an abundant supply of water. Production up to a thousand gallons a minute may be obtained from large wells that encounter several large internal channels.

Wells that do not encounter solution channels in the upper 350 feet of limestone rarely prove successful at greater depths.

Water from these limestones is generally moderately hard but fairly low in iron.

Upper Ordovician, Silurian, and Devonian rocks. A second group of rocks with a generally intermediate ground-water yield is shown as symbol D on the map. This group consists of upper Ordovician shales and sandstones, and Silurian and Devonian sandstones, shales, and limestones. The various types of rocks included differ in the quantity of water they yield to wells, but on the whole they produce somewhat comparable quantities of water.

Sandstones of upper Ordovician and Silurian age yield moderate supplies of water, with wells in the Silurian sandstone of Clinton age producing up to 350 gallons a minute. The water is generally softer than from limestone sources. Limestones of Silurian age may give greater yields but production is dependent upon encountering solution channels and success of a well is uncertain. Rocks of upper Ordovician and Silurian age occur in the highly folded Ridge and Valley section of Pennsylvania. Therefore, a formation favorable for ground-water development may have a very narrow belt of outcrop with a corresponding limit to its use for ground water.

Devonian rocks have a much greater area of outcrop, being particularly widespread in the northeast section of the State. The aggregate thickness of Devonian rocks is several thousand feet. They are largely marine sediments but the Catskill shales, sandstones, and conglomerates of upper Devonian age are fresh-water sediments.

Limestones of Devonian age may yield fairly large quantities of water, up to 500 gallons a minute, where solution channels are encountered. Such wells usually produce hard water. The Ridgeley sandstone of lower Devonian age locally yields large quantities of soft water in central Pennsylvania. The Catskill sediments produce considerable quantities in northeastern areas of the State.

Mississippian and all but youngest Pennsylvanian rocks. The third group of rocks that yield intermediate supplies of ground water is composed of sandstones and shales of Mississippian age and all but the youngest formation of Pennsylvanian age. (Symbol E on map.)

The Mississippian Pocono sandstone formation is the most favorable source of ground water in this group. The formation is widespread, but is best utilized for water in eastern Pennsylvania where large yields of very good water have been developed locally. In central Pennsylvania this formation is highly folded and occurs as narrow resistant ridges, generally unsuited to water development. In the western part of the State the formation yields 300 to 600 gallons a minute in places, but the water is of poor quality, being high in iron content, and in places salty. The shale formation (Mauch Chunk), which overlies the Pocono sandstone, yields some water, but in western Pennsylvania its water may be salty and iron-bearing.

Rocks of Pennsylvanian age mapped with this group produce moderately large supplies from sandstone members. The water is of good quality in the eastern part of the State but it generally contains iron in western areas. The greatest production can be expected from the lowest formation of Pennsylvanian age, the Pottsville sandstone.

Triassic system. Two groups are shown on the map as areas where conditions for ground-water development are generally poor. The more favorable of these two groups is the Triassic belt shown by the symbol F on the map.

Rocks of Triassic age in Pennsylvania are mostly shales, with some sandy and conglomeritic members. In general, yields from wells in Triassic rocks are small, but some wells in the sandstone and conglomerate portions yield as much as 200 to 300 gallons a minute. The waters are generally hard and may contain considerable iron.

Pre-Cambrian, lower Cambrian, upper Pennsylvanian and Permian rocks. The last group, shown by symbol G on the map, is believed to possess in general the least favorable conditions for ground-water production. This group consists of pre-Cambrian gneiss, schist, and granite, lower Cambrian sandstones and quartzites, upper Pennsylvanian shales, sandstone, and coal, and Permian rocks. Locally, these rocks contain moderate amounts of water but as a whole they are not comparable to the groups described earlier. Rocks of upper Pennsylvanian and Permian age are restricted to the southwestern part of the State. Water from these rocks may be hard and iron-bearing. The rocks of pre-Cambrian and lower Cambrian age occur in southeastern Pennsylvania and yield small amounts of water, which is generally of good quality.

Summary. The map accompanying this brief survey of Pennsylvania's ground-water distribution is not intended to serve as a guide for detailed use. For specific localities the reader is referred to the Pennsylvania Geological Survey ground-water bulletins cited previously. The map is intended to outline broad groups of rocks, which by virtue of certain conditions are considered generally good, intermediate, or poor for the development of ground water in quantities that might be of value to industries. In order that the best use of the map may be made, the following information should be emphasized.

Figures of water production that have been used in describing quantities obtainable from various formations or types of rock are maximum figures listed for known wells. Most of the wells in Pennsylvania recorded by the State and federal geological surveys are small domestic and stock wells, and a true average for large wells such as required by industries cannot be given from the data now available. The known variation in yield in a single formation or similar type of rock is admitedly great, particularly in limestone. The largest quantities of ground water may be expected from glacial lake and stream deposits, Cretaceous sands and gravels in southeastern Pennsylvania, and perhaps from wells encountering especially large or numerous channels in Cambrian and Ordovician limestones.

Sandstones of Silurian, Devonian, Mississippian, and Pennsylvanian age are generally dependable for intermediate quantities. Limestones of the same age may yield greater quantities in places than sandstones, but again may yield no water where solution channels are not encountered. As a rule, shales are less productive than either sandstones or limestones.

The shales of upper Pennsylvanian, Permian, and Triassic age are not promising. Pre-Cambrian and lower Cambrian rocks may yield moderate amounts from fissures but this condition is not believed common.

Quality of ground water over the State is extremely variable, even within a single formation. In general, limestone waters are harder than sandstone waters. Iron and salt-bearing waters are common in western Pennsylvania, particularly in the region of coal mining. Salt in ground water is most common in rocks producing from a considerable depth.

SURFACE-WATER RESOURCES

Pennsylvania Department of Forests and Waters

Systematic studies of Pennsylvania's surface-water resources, including the collection of data in regard to the flow of streams, are conducted by the Pennsylvania Department of Forests and Waters in cooperation with the United States Geological Survey. At the present time, 158 regular stream-flow gaging stations are operated in Pennsylvania.

With the growth of the Commonwealth more and more attention is necessarily being given to the wise development and efficient utilization of our water resources and the equitable distribution of its waters, particularly among those who use the same source of supply. At the present time, the most important considerations of water relate to (a) municipal and industrial supplies; (b) industrial uses, especially for certain processes that require large quantities of clear water with certain standards of chemical purity; (c) problems of floods and their control; (d) availability of supplies for storage and regulatory works; (e) recreation; (f) transportation by navigation along the Allegheny, Monongahela, and Ohio Rivers; (g) generation of water power; (h) and generation of steam power for which large quantities of water are required for condensers.

Beginning with 1922, stream flow records collected in Pennsylvania have been published annually in State reports entitled, "Stream Flow Records of Pennsylvania." Records previous to and including those for 1911, were published in the annual reports of the Water Supply Commission. Since cooperation was begun with the United States Geological Survey in

1931, the records have also been published annually in Part I (North Atlantic Slope Basins) and Part III (Ohio River Basin) of the Water Supply Papers of the United States Geological Survey.

The following special cooperative hydrologic reports have also been published by the Pennsylvania Department of Forests and Waters in recent years.

The Drought of 1930 in Pennsylvania
The Floods of March 1936 in Pennsylvania
Flood Discharge Records relating to Pennsylvania Streams
Natural Water Losses from Pennsylvania Drainage Basins
Elevations of Major Floods along Pennsylvania Rivers
The Floods of May 1942 in the Delaware and Lackawanna River Basins
The Flood of July 1942 in the Upper Allegheny River and Sinnemahoning Creek Basins

Stream flow records are now available of 102 locations on Pennsylvania streams where 10 years or more of continuous records have been obtained. The records of flow for the minimum day and the average flow during the period of record are given in the following tabulations. Detailed information, not only on discharge but also on river heights at these locations and at many others, may be obtained from the Department of Forests and Waters.

Data on the next table are explained thus:

The column headed "Average minimum day" is obtained by averaging the lowest daily flow in cubic feet per second for each year of record.

The column headed "Minimum year" is the lowest yearly mean flow in cubic feet per second occurring during the period of record.

The column headed "Average year" is obtained by averaging yearly mean flows in cubic feet per second for each year of record.

SUMMARY OF MINIMUM AND AVERAGE FLOWS AT PENNSYLVANIA GAGING STATIONS HAVING TEN YEARS OR MORE OF RECORD

Number on map	*Name of stream*	*Location All in Pennsylvania except first four*	*Drainage area (square miles)*	*Number of years of record*	*Discharge in cubic feet per second*			
					Minimum day	*Average minimum day*	*Minimum year*	*Average year*
	DELAWARE BASIN							
1	Delaware River	Port Jervis, N. Y.	3076	37	175	632	3560	5526
2	Delaware River	Belvidere, N. J.	4542	20	785	1221	5131	7920
3	Delaware River	Riegelsville, N. J.	6344	36	906	1786	7025	10920
4	Delaware River	Trenton, N. J.	6796	29	1240	2030	7454	11530
5*	Lackawaxen River	West Hawley	206	14	16	32	187	352
6	Lackawaxen River	Hawley	290	12	7	27	268	421
7	Wallenpaupack Creek	Wilsonville	228	26	....	....	204	365
8	Bushkill Creek	Shoemakers	117	30	4	20.6	141	234
9*	McMichaels Creek	Stroudsburg	64.4	25	9	22	63.3	122
10	Lehigh River	Tannery	322	23	7.2	92.5	374	661
11	Lehigh River	Bethlehem	1280	33	160	441	1280	2144
12*	Tohickon Creek	Point Pleasant	107	30	0	2.8	116	202
13*	Neshaminy Creek	Rushland	134	31	1	9.6	161	229
14*	Schuylkill River	Reading	900	16	117	248	1150	1531
15	Schuylkill River	Pottstown	1147	15	175	342	943	1801
16	Schuylkill River	Philadelphia	1893	20	7	205.6	1456	2617
17	Little Schuylkill River	Tamaqua	42.9	24	3	9.8	34.8	90.5
18*	Perkiomen Creek	Frederick	152	29	4	18.7	174	252
19	Perkiomen Creek	Graters Ford	279	18	5.6	25.5	189	394
20	Ridley Creek	Moylan	31.9	11	3.1	10.4	28.3	42.4
21	Chester Creek	Chester	61.1	11	6.5	16.0	54	75.8
22	Brandywine Creek	Chadds Ford	287	31	50	113	235	375
	SUSQUEHANNA BASIN							
23	Susquehanna River	Towanda	7797	24	393	996	6378	9877
24	Susquehanna River	Wilkes-Barre	9960	43	625	1319	8074	13283
25	Susquehanna River	Danville	11220	39	722	1556	9250	14967
26	Susquehanna River	Harrisburg	24100	52	1700	4230	20730	34197
27	Susquehanna River	Marietta	25990	11	1380	3386	22490	33134
28	Towanda Creek	Monroeton	214	24	0.7	9.2	162	275
29	Tunkhannock Creek	Dixon	383	24	9	29	265	520

* Station discontinued.

SUMMARY OF MINIMUM AND AVERAGE FLOWS AT PENNSYLVANIA GAGING STATIONS HAVING TEN YEARS OR MORE OF RECORD—Continued

Number on map	*Name of stream*	*Location*	*Drainage area (square miles)*	*Number of years of record*	*Discharge in cubic feet per second*			
					Minimum day	*Average minimum day*	*Minimum year*	*Average year*
30*	Lackawanna River	Moosic	265	12	72	104	356	506
31	Wapwallopen Creek	Wapwallopen	45.8	22	2.2	4.9	34.1	60
32*	Fishing Creek	Bloomsburg	355	12	7	37	372	638
33	West Branch Susquehanna River	Bower	315	29	16	36	296	544
34	West Branch Susquehanna River	Renovo	2975	30	80	279	2828	4653
35	West Branch Susquehanna River	Williamsport	5682	47	250	746	5287	8731
36	Clearfield Creek	Dimeling	371	29	7.1	32.1	322	562
37	Driftwood Branch Sinnemahoning Creek	Sterling Run	281	23	0.4	16.3	244	435
38*	North Bald Eagle Creek	Milesburg	119	19	1	7.4	116	210
39	North Bald Eagle Creek	Beech Creek Station	559	32	25	138	478	773
40	Pine Creek	Cedar Run	604	23	5.8	36.2	426	739
41*	Pine Creek	Waterville	750	11	25	74	1027	1151
42	Lycoming Creek	Trout Run	173	25	4	18.1	164	254
43	Loyalsock Creek	Loyalsock	443	17	13	40.1	451	681
44	Penn Creek	Penns Creek	301	13	26	42	257	386
45	Mahantango Creek East	Dalmatia	162	13	1.5	10.9	71.7	204
46	Frankstown Branch Juniata River	Williamsburg	291	23	31	55.6	233	382
47*	Frankstown Branch Juniata River	Huntingdon	816	20	75	190	718	1138
48	Juniata River	Newport	3354	41	286	567	2300	4340
49	Standing Stone Creek	Huntingdon	128	12	7.6	12.9	85.1	137
50	Raystown Branch Juniata River	Saxton	756	31	53	112	417	918
51	Brush Creek	Gapsville	36.8	11	0.3	1.2	29.4	45.5
52	Great Trough Creek	Marklesburg	84.6	12	0.8	3.0	59.6	90.8
53	Tuscarora Creek	Port Royal	214	31	1	10.4	131	255
54	Cocolamus Creek	Millerstown	57.2	12	1.3	2.9	34.9	68.5
55	Sherman Creek	Shermandale	200	13	10	18.8	123	261
56	Conodoquinet Creek	Hogestown	470	13	26	85	245	522
57	Swatara Creek	Harper Tavern	333	23	9	41.4	203	537
58*	Upper Little Swatara Creek	Pine Grove	34.3	12	1.7	4.4	24.6	53.3
59	West Conewago Creek	Manchester	510	13	2	20.5	153	536
60	Codorus Creek	Spring Grove	74.3	12	1.6	8.1	51.2	75.9
61	South Branch Codorus Creek	York	117	15	0.1	14.9	45	129
62	Conestoga Creek	Lancaster	322	12	7	41.8	153	354
	POTOMAC BASIN							
63*	Licking Creek	Sylvan	158	11	4.9	10.2	104	166
	OHIO BASIN							
64*	Allegheny River	Larabee	541	15	3.5	29.0	503	805
65	Allegheny River	Franklin	5982	24	335	746	6190	9681
66	Allegheny River	Parkers Landing	7671	10	454	874	7708	11670
67	Allegheny River	Kittanning	8973	30	570	1163	9247	15840
68	Brokenstraw Creek	Youngsville	321	28	19	42.9	276	539
69*	Tionesta Creek	Nebraska	469	15	27	46.4	527	842
70	Oil Creek	Rouseville	300	10	23	39.9	274	459
71*	Oil Creek	Near Rouseville	315	20	23	49.0	379	567
72	French Creek	Carters Corners	208	26	7.0	18.6	232	407
73*	French Creek	Saegerstown	629	18	24	53.8	651	1050
74*	French Creek	Carlton	998	14	65	119	1167	1730
75	French Creek	Utica	1028	10	45	85.3	999	1494
76	Sugar Creek	Sugarcreek	166	10	10	23.2	145	235
77*	Cussewago Creek	Meadville	90.2	28	0	1.59	79.8	129
78*	Clarion River	Clarion	930	18	30	134	1146	2041
79	Clarion River	Piney	951	19	0	55.8	989	1564
80	Redbank Creek	St. Charles	528	29	10	42.9	470	863
81*	Mahoning Creek	Dayton	321	20	8.5	26.7	320	556
82	Crooked Creek	Crooked Creek Dam	280	31	0.1	6.59	230	424

* Station discontinued.

SUMMARY OF MINIMUM AND AVERAGE FLOWS AT PENNSYLVANIA GAGING STATIONS HAVING TEN YEARS OR MORE OF RECORD—Continued

Number on map	*Name of stream*	*Location*	*Drainage area (square miles)*	*Number of years of record*	*Discharge in cubic feet per second*			
					Minimum day	*Average minimum day*	*Minimum year*	*Average year*
83*	Stony Creek	Johnstown	467	22	11	40.9	343	705
84*	Kiskiminitas River	Avonmore	1723	29	65	292	1722	2994
85	Blacklick Creek	Blacklick	390	35	6	33.0	381	657
86*	Loyalhanna Creek	New Alexandria	265	17	2.7	25.2	255	442
87	South Fork of Tenmile Creek	Jefferson	180	10	0.1	0.82	132	208
88	Youghiogheny River	Connellsville	1326	33	11	141	1210	2475
89	Youghiogheny River	Sutersville	1715	17	57	230	2030	2894
90	Casselman River	Markleton	382	22	11	31.6	317	613
91	Big Piney Run	Salisbury	24.5	9	0.18	0.67	22.2	37.6
92	Laurel Hill Creek	Ursina	121	26	1	8.44	146	258
93	Turtle Creek	Trafford	55.9	22	0.1	1.76	44.5	76.6
94	Chartiers Creek	Carnegie	264	13	16	24.7	212	334
95	Beaver River	Wampum	2235	10	97	264	948	2031
96*	Shenango River	Jamestown	181	13	1.3	4.4	140	222
97*	Shenango River	Sharon	608	27	7.5	27.3	303	674
98*	Shenango River	New Castle	792	24	7.9	26.7	505	886
99	Little Shenango River	Greenville	104	22	3.0	6.69	75.5	135
100	Pymatuning Creek	Orangeville	169	24	0.6	3.70	82.7	200
101	Connoquenessing Creek	Hazen	356	23	6.5	16.4	291	477
102	Slippery Rock Creek	Wurtemburg	406	29	12	34.8	297	550

* Station discontinued

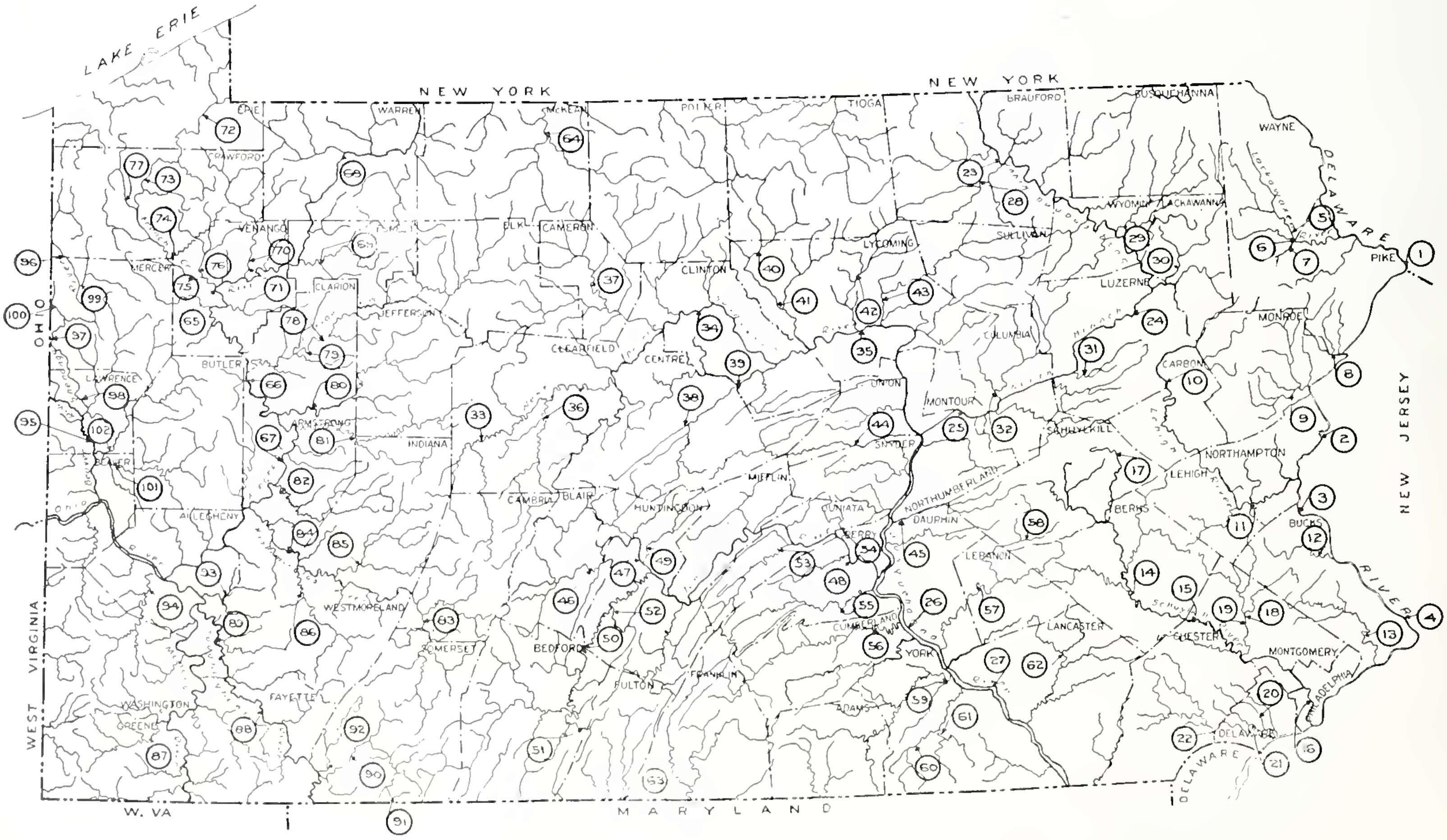


FIGURE 12. MAP SHOWING LOCATION OF STREAM-FLOW GAGING STATIONS

MINERAL RESOURCE AREAS OF PENNSYLVANIA

The State may be divided readily into fourteen areas in each of which the topography, the underlying rocks, and the mineral resources are different from the others. These areas, shown in figure 13, and their dominant characteristics are as follows:

Coastal Plain. The western edge of the Coastal Plain, occupies a narrow strip along the Delaware River from Morrisville to Marcus Hook. It is slightly above sea level, usually flat and terraced, and underlain by sand, gravel, and loosely consolidated sediments laid down by the Delaware and its tributaries and by the sea during recent periods of submergence. The deposits are of Recent, Tertiary, and Cretaceous age, the last occupying only a few square miles. The beds lie nearly flat. They consist of the Cape May formation, 40 feet thick, and the Pensauken, 30 feet thick. These beds make several terraces from sea level up to 180 feet above sea level. The mineral resources are: first, water in abundance; second, abundant sand and gravel; third, small bodies of clay.

Piedmont Highland. A belt of very old metamorphosed and igneous rocks, covering parts of southern Bucks, Montgomery, Chester, Lancaster, and York Counties and northern Philadelphia and Delaware Counties, constitutes the Piedmont Highland; also a detached area north of the Chester Valley (Mine Ridge and Welsh Mountain). The topography is that of a sharply dissected plateau. The upland surface of this plateau rises from 250 feet adjoining the Coastal Plain to 450 feet in central Montgomery County and 1,000 feet in southern York County. Through this uplifted surface the streams flowing southeast cut narrow, deep ravines or gorges. Some of the inter-stream divides at the east are still mantled with a deposit of sand and gravel (Bryn Mawr formation) of Tertiary age. The rocks of the area are granite, gabbro, gneiss, schist of several types, serpentine, pegmatite, crystalline limestone, and slate of pre-Cambrian or early Paleozoic age, bordered at the north, and in infolded lenses, by younger lower Cambrian quartzites. See table under Order of Rocks. Many diabase dikes of Triassic age cut across the other rocks. The structure of the rocks is complex. Local intrusions and several stages of metamorphism attending intense folding and faulting make a confused geologic history.

The mineral resources of this area consist first of the rocks themselves, partly listed above, which have

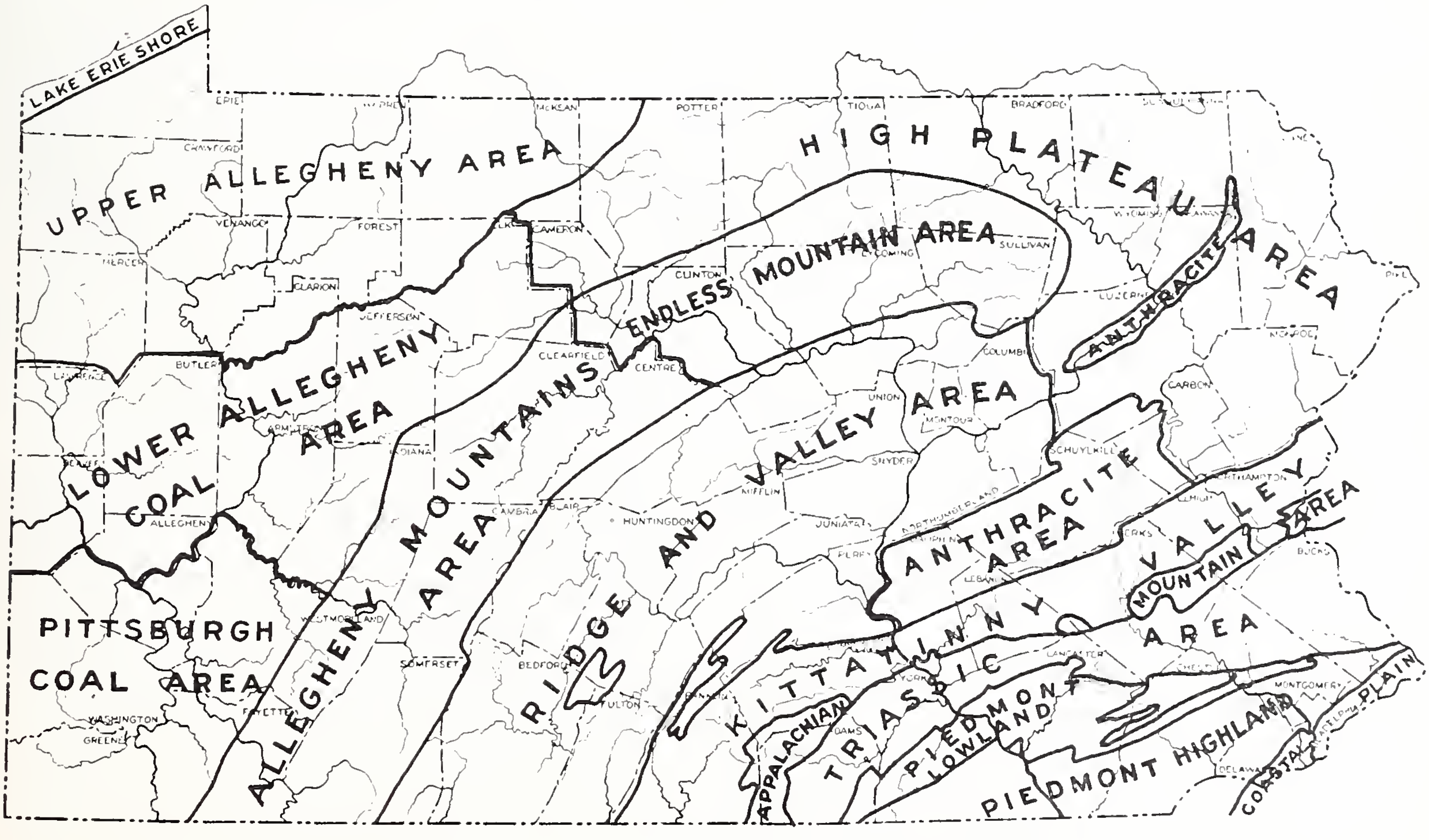


FIGURE 13. MAP SHOWING BOUNDARIES OF MINERAL RESOURCE AREAS

value for building and as crushed stone. They include sand and gravel from the unconsolidated deposits on the divides or from the disintegration of bedrock. Associated with pegmatites are feldspar, kaolin, quartz, and mica. Nickel ores are associated with peridotite and chrome ores with serpentine. The known deposits of chrome ore are exhausted; others may occur. The Pickering gneiss is graphitic and locally contains considerable graphite. The area also contains limestone and marble, which may be used for building stone, lime, cement, and road building.

Piedmont Lowland. The Piedmont Lowland consists of valley land forming a rather narrow belt, except around Lancaster, which is underlain by Cambro-Ordovician limestones and Ordovician shales. Thrust faults of large displacement locally bound the lowland. A large part of this area lies between 400 and 500 feet above sea level. Many areas are nearly level over several square miles, but fault blocks and differences in resistance to erosion of the underlying rocks result in irregular areas rising to 600 feet or higher.

The rocks of this area and their approximate thickness are:

		Feet
Lower Ordovician or Blount (?), Conestoga limestone		1000
Cocalico shale		2000
Middle Canadian, Beekmantown limestone		2000
Lower Canadian, Conococheaque limestone		1000
Upper Cambrian, Elbrook limestone		1000
Lower Cambrian		
Tomstown group	Ledger dolomite	1000
	Kinzers formation	200
	Vintage dolomite	600
Antietam quartzite		300

The rocks are highly folded and faulted and locally the limestones are schistose. The shales of late Ordovician age occur in this belt only in northern Lancaster County.

The principal mineral resource of this area is limestone used for building, crushed stone, lime, cement, and flux, and dolomite used for making magnesia and magnesium products. Associated with the limestone are small deposits of lead, zinc, and some other minerals of possible commercial value. Near Conshohocken in the Chester Valley the hilltops are covered with what appear to be Cretaceous strata, yielding clays of value. Locally marble has been used on a small scale. Shales for making brick, tile and terracotta occur in northern Lancaster County.

Triassic Area. The Triassic rocks consist of shales, sandstones, and conglomerates, typically red; diabase (trap) dikes and sills, and baked shales adjoining the diabase. They form a belt from 4.5 to 30 miles wide, covering most of Bucks County and extending west and south from the Delaware to cover most of Adams County at the Maryland line. Because of the variable character of these rocks, the surface is commonly a rolling upland 300 to 600 feet above sea level, above which trap rock ridges rise sharply several hundred feet.

The succession is as follows:

AT THE WEST	*Feet*
Fanglomerate	
Gettysburg shale	3,200
Heidlersburg sandy member	4,800
Gettysburg shale	7,500
New Oxford group	6,900
Total	22,400

AT THE EAST	*Feet*
Fanglomerate	
Brunswick red shale	13,000
Lockatong dark shale	3,500
Stockton sandstone and conglomerate	3,000
Total	19,500

The mineral values are derived mainly from the trap rocks which are extensively used as crushed stone, for structural purposes, or polished as "black granite." Adjoining the trap rocks in several places are, or have been, large deposits of magnetic iron. One of these at Cornwall, Lebanon County, has been mined for over 200 years and still holds large reserves. The baked shale bordering some of the trap has been used for roads and may make higher ridges than the trap itself. Formerly Triassic brown sandstone was much used for building stone, but its use has declined to little or nothing. A limestone breccia on the edge of the area in places has been used as a marble (Potomac). The Triassic sediments dip northwest or north from a few degrees to 60° or more. As a rule they impinge against a great fault on the north and west side. Normal faults are common.

Appalachian Mountain Area. (See map.) Three small areas, one almost entirely in western Adams County, one extending from Reading to the Delaware River just south of Easton, and a third near Wernersville, represent the Appalachian Mountain Area. The area is characterized by mountainous topography and consists of pre-Cambrian igneous and metamorphosed rocks overlain by hard quartzite of Lower Cambrian age that flanks the other rocks and has much to do with the height of the mountains.

The Adams County area consists of altered lavas, flanked by the Lower Cambrian quartzites. The section is:

	Feet
Lower Cambrian	
Antietam sandstone	800
Harpers schist	3,000
Weverton sandstone	750
Pre-Cambrian	
Loudoun formation	500
Metabasalt	
Aporhyolite	

The eastern area consists of granites, gabbro, diorite, monzonite, and granitic gneisses. The succession is:

Hardyston formation, unconformable above the rest
Byram granite, gneiss, and pegmatites
Pochuck gneiss
Moravian Heights formation
Franklin graphitic limestone and schist

South Mountain in Adams County is 2,100 feet high, in Lebanon County and farther east 1,000 to 1,200 feet. See the relief map, figure 14.

The mineral resources consist of the rocks listed above used for building or structural purposes. One of these rocks, metabasalt (called greenstone), is much used in ground form for artificial roofing and other purposes. At the foot of the mountains are mineable quantities of iron ore and ocher. The rocks of this area form the centers of great anticlines, are much broken by faulting, and enclose many small areas of younger rocks.

Kittatinny Valley. (See map.) The Kittatinny Valley, 12 to 20 miles wide, lies between the Appalachian Mountains on the south and east (South Mountains) and Kittatinny Mountain on the north and west. The south side of the valley is underlain by Cambro-Ordovician limestones and the north side by Ordovician shale (locally transformed into slate). The limestone area from the Delaware to the Susquehanna commonly is sub-level and from 400 to 500 feet above sea level; in Franklin County it is 600 to 800 feet. The shale to the north forms rough or hilly land commonly somewhat higher. At the east a shaly limestone lying between the shale or slate and the limestone or dolomite supports a large cement industry. The limestones are used extensively for crushed stone, lime, flux stone, and cement, and occasionally for building. At the contact with the underlying quartzites, commercially important iron ores occur, locally with manganese and white clay. The iron ores formerly mined extensively may still have some value. In Lehigh and Northampton Counties the upper shales have been compressed into slate and support a large slate industry. The rocks of this area are highly folded and locally contorted.

The rocks underlying the Kittatinny Valley are as follows:

AT THE WEST	*Feet*
Silurian	
Tuscarora sandstone	270
Ordovician	
Juniata formation	450
Bald Eagle sandstone	300
Martinsburg shale	2,000
Chambersburg limestone	500
Canadian	
Stones River limestone	850
Beekmantown limestone	2,300
Conococheaque limestone	1,600
Cambrian	
Elbrook formation	3,000
Waynesboro formation	1,000
Tomstown limestone	1,000
Antietam sandstone	

AT THE EAST	*Feet*
Silurian	
Shawangunk sandstone	500-1800
Ordovician	
Juniata formation	?
Bald Eagle sandstone	?
Martinsburg shale	6,000
unconformity	
Jacksonburg limestone	100-700
Canadian	
Beekmantown limestone	1,200
Allentown limestone	1,500
Cambrian	
Tomstown limestone	1,000
Hardyston sandstone	25-200

Ridge and Valley Area. The Ridge and Valley Area, 45 to 70 miles wide and 150 miles long, covers the eastern-central part of the State between Kittatinny Mountain on the east and Allegheny Mountain on the west and north. The rocks are, in brief, several thousand feet of Silurian and 8 to 10 thousand feet of Devonian, all highly folded, with several windows exposing rocks down to the middle Cambrian, and a few outliers of Mississippian and Pennsylvanian rocks. The three massive sandstones, Tuscarora, Pocono, and Pottsville at the base of the Silurian, Mississippian, and Pennsylvanian respectively, are relatively thin and turned up on edge in the high folding, and make long narrow mountains, separated by broad valleys which are underlain by the much thicker shales, soft sandstones, and limestones. The drainage finds outlet to the southeast by scenic water gaps which cut the narrow ridges. The whole drainage system makes a grape-arbor pattern and the gaps facilitate transportation and travel.

The strata underlying this broad belt are very thick and change considerably from east to west and south to north. The following section is taken from Centre County on the west side of the belt and would not be characteristic of Perry County on the east side of the belt, especially as to the thickness of the beds. Thus, in Perry County, the Mauch Chunk is 2,000 to 3,000 feet thick, the Pocono 1,600, the Catskill 4,500, the Chemung 500 feet. However, many elements go through the entire belt. Though taken in the main from the report on the Bellefonte area, a few strata missing from that area but present nearby have been inserted:

STRATA UNDER RIDGE AND VALLEY AREA
(Western Part)

	Feet
Pennsylvanian	
Pottsville series	0-280
Mississippian	
Mauch Chunk formation	0-200
Pocono formation	1,100
Devonian	
Catskill formation	1,600
Chemung formation	2,700
Portage group	1,500
Genesee group	350
Tully limestone	0-200
Hamilton formation	600
Marcellus shale	100
Oriskany sandstone	170
Helderberg limestone	150
Silurian	
Tonoloway limestone	400
Wills Creek shale	400
Bloomsburg red beds *	0
McKenzie limestone	200
Silurian (continued)	
Clinton formation	800
Tuscarora quartzite	400
Ordovician	
Juniata shale and sandstone	1,000
Bald Eagle sandstone	800
Reedsville shale	1,000
Trenton limestone	600
Black River limestone	180
Canadian	
Stones River limestone	400
Bellefonte dolomite	1,500-2,200
Axemann limestone	360
Nittany dolomite	1,200
Stonehenge limestone	630
Cambrian	
Mines dolomite	200
Gatesburg formation	1,600
Warrior limestone	250-1,200

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* Although lacking in the center of the State, eastward the red element increases until on the Delaware the bulk of the Middle and Upper Silurian is red.

The mineral resources of the area consist of the Tuscarora ganister for building stone and the making of silica brick, red hematite bedded iron ore in the Clinton from 1 to 3 feet thick, red brick shale in the Middle and Upper Silurian; impure limestone in the Upper Silurian and Lower Devonian, suitable for building and the less exacting uses of limestone; the Oriskany sandstone widely very pure and suitable for glass sand, molding sand, and building sand; a great thickness of medium-soft sandstone and shale, used locally for minor building purposes or for brick or tile. Where upfolded or exposed in valleys, the Cambro-Ordovician limestones are of high value and extensively quarried for lime and flux; associated with this limestone have been extensive deposits of limonite ore, some of which may still be of value, and minor deposits of lead and zinc. Two small areas of Coal Measures are preserved in synclines. The Broad Top field in Bedford, Fulton, and Huntingdon Counties contains several coal beds of the Allegheny formation that have been mined for more than 100 years. The Wellersburg coal field in the southeast corner of Somerset County contains the Pittsburgh and lower coal beds.

Anthracite Area. The Anthracite areas are of limited extent, really the eastward extension of the preceding area, but differ in three respects: first, the folding is more intense and so deep that up to 3,500 feet of Coal Measures have been infolded; second, the sandstones of the Mississippian and Pennsylvanian are more massive and resistant, resulting in much more mountainous and broken land with narrower valleys; third, the presence of thick beds of coal, converted into high-grade anthracite. The massive sandstones just mentioned become more massive to the east until, in the High Plateau Area, they formed a huge buttress that resisted folding and transmitted the pressure to form a major synclinal coal basin, the Northern Anthracite field.

The Anthracite areas consist of four fields; long, narrow, major underturned synclines, carrying many minor folds, bounded and broken by high ridges of the basal Pottsville conglomerate. The Southern field is long and continuous. Two groups of detached and semidetached basins form the Eastern and Western Middle fields. The Northern field is considerably detached from the others. The rocks consist of the Pottsville conglomerate and the Coal Measures. The Pottsville is 200 feet thick at the northeast and 1,475 feet at the southwest. Commonly the Pottsville lacks workable coal, but locally, as in the Lykens area, contains coal beds up to 16 feet thick. Much of the conglomerate is coarse but the pebbles decrease in abundance to the northeast.

The Coal Measures, up to 2,500 feet thick, contain many thick beds of coal. The Mammoth bed locally contains over 100 feet of coal and in places is split and spread until 290 feet thick, the splitting rocks being in places coarse conglomerate. Most of the beds are split, and though traceable, are extremely variable in thickness from place to place. The metamorphosis of the coal increases from the western end to the Pocono Plateau, where the percentage of fixed carbon is highest. Folding of the rocks and crushing of the coal is most pronounced in the Southern field and least in the Northern field. The crushed condition of the coal in the Southern field increases the cost of mining in that area.

The under clays, so important in the bituminous fields, are lacking or too thin and slatey to have much value. Limestone, likewise, is all but lacking. When anthracite mining ceases, or before, the region holds promise of becoming a great recreational center for the people from New York, Philadelphia, and other centers, attracted because of its nearness, its high altitude, and the rugged, mountainous character of the terrain. The pits formed by stripping, when filled with water may be used for swimming, boating, and skating; and culm banks when subdued by the hand of time and of man become places for tobogganing, horseback riding, and other sports. The anthracite area may again become as it was called in the early days, St. Anthony's wilderness, a place to go to for a good time.

Allegheny Mountains Area. The high plateau lying between and including the Allegheny Mountain on the east and Chestnut Ridge on the west, is here called the Allegheny Mountains Area. It is about 35 miles wide from east to west and 125 miles long. It includes the highest land in the State, 3,200 feet, on the top of Negro Mountain near the Maryland line, descending to about 1,800 feet for much of the area at the northeast, though rising to 2,200 feet or more over a broad arch in northern Clearfield County. The mountain tops rise from 2,400 feet to 3,150 feet above sea level. Unlike the Ridge and Valley mountains, most of which are monoclinal, as is Allegheny Mountain, the others, Negro Mountain, Laurel Hill, and Chestnut Ridge, are anticlinal. The rocks consist almost entirely of the Coal Measures of Pennsylvanian age.

The folding is gentle, except in the arches of Chestnut Ridge and Laurel Hill and in Allegheny Mountain, ranging from sublevel to 400 feet to the mile. At the south, the anticlines expose the underlying Mississippian and Devonian in side ravines and locally at the top of the arches.

The Mississippian in this area contains the Greenbrier limestone near the base of the Mauch Chunk in the southern part of the area and the Loyalhanna sandy limestone or limey sandstone at the base of the Mauch Chunk. The latter has been extensively quarried or mined for ballast and road building. It may prove of value for making mineral wool. The underlying Pocono sandstone up to 1,100 feet thick may be used locally for building stone. Below these strata and below the surface is the Devonian, which has produced a small amount of natural gas from the "Speechley," the Onondaga, Oriskany, and Newburg horizons.

The Pennsylvanian in this area includes the Pottsville, Allegheny, Conemaugh, and Monongahela formations. The Pottsville consists of the Connoquenessing and the Homewood sandstones, useable for large structural work and silica sand, and the Mercer beds. The coal generally has little value but the Mercer fire clay locally is high-alumina, used for very refractory brick, and possibly can be used as a source of aluminum.

The Allegheny formation, about 250 feet thick, includes the Freeport, Kittanning, Clarion, and Brookville coals, and their underclays, several more or less massive and useable sandstones, and local limestones. The coals of this formation are the most valuable mineral resource of the area.

The Conemaugh formation is about 800 feet of shales, sandstones, thin coals, and thin limestones, none of great value but all used locally.

The Pittsburgh coal at the base of the Monongahela formation escaped erosion in the deeper synclines, especially north of Ligonier and between Berlin and Salisbury, but has largely been mined out.

Besides the mineral resources mentioned, natural gas is produced on Chestnut Ridge in Fayette County.

Pittsburgh Coal Area. All of the land west of Chestnut Ridge and south of the Kiskiminetas-Allegheny-Ohio channel, except the south end of Beaver County, is here called the Pittsburgh Coal Area, because it contains the great Pittsburgh coal bed, the most valuable single mineral deposit in the world. Small outliers of this coal occur north and east of the area. See figure 13.

This corner of the State is part of the Appalachian Plateau Province. In the north and east parts of the area the concordant hilltops are 1,200 to 1,300 feet above sea level, and rise gradually to 1,600 feet in the southwest corner. Drainage changes connected with the Ice Age lowered the river level at Pittsburgh from 900 to 700 feet above sea level and as a result the principal streams are sharply entrenched.

The rocks in the area range from the Chemung group of Upper Devonian age, which crops out on the west side of Chestnut Ridge, to the Greene group of Permian age, the surface rock in western Greene

County and adjacent part of Washington County.

The Pittsburgh coal bed is primarily responsible for the great industrial development of the Pittsburgh area. It ranges in thickness from 4½ to 6 feet in the northern part to an average of 9 feet in the southern part of the area. It is high-grade steam coal in the northwest part, high-grade gas coal in the northeast, and high-grade coking coal in the southern part. This coal is in the hilltops in the northern part and about 800 to 1,400 feet below the surface in the southwest corner of the area.

The Sewickley and Waynesburg coals are the principal ones above the Pittsburgh that are mineable. The Upper Freeport is the most extensively mined of the several mineable coals in the Allegheny group.

Sand and gravel are abundant in the river channels and in oxbows and terraces at higher levels. Annual production is large.

Aside from the coal and sand and gravel, the area contains much shale, sandstone, and limestone and small amounts of clay and less iron. The sandstones have been used to a small extent for local building. A sandstone near Waynesburg has the appearance and apparently the wearing qualities of the famous Indiana stone so extensively used for building all over the United States. It is not known if it is in sufficient volume with the same high quality to warrant extensive development. The limestones are abundant but not of high quality. The thicker beds average 80 to 85 percent calcium carbonate and are suitable for ag-lime. Some day they may be of value in neutralizing the acid mine waters of the district. They have value as road ballast.

Plastic and flint clays of the Allegheny formation have been mined on the lower west slope of Chestnut Ridge and on the Youghiogheny above Layton. They crop out also on Jacobs Creek west from Tyrone Mills. Further prospecting in these and the Conemaugh beds might bring to light some good quality clays, although in some areas none appear to be of much value. Elsewhere in the area they are below drainage and if proven of value would have to be mined by shaft or slope. The "main" clay of the Pittsburgh coal bed, 10 to 12 inches thick, has been used for minor refractory products.

Some of the shales in the area, especially some in the Conemaugh group, are suitable for making brick and tile.

A little oil occurs in sands of Conemaugh and Allegheny age, but most of the oil and gas here, as elsewhere, comes from the Devonian sands, from the First sand or Hundred-foot to and including the Elizabeth sand, possibly equivalent to one of the Warren sands of northern Pennsylvania. The Fifth and Bayard or Sixth sands are the largest producers. The Oriskany and Onondaga beds on Chestnut Ridge and on other anticlines to the northwest have furnished some gas. Natural gas occurs in most of the area west of Monongahela River, and in the northern part of Westmoreland County. Most of the oil pools are in the western third of the area.

Lower Allegheny Coal Area. The Lower Allegheny Coal Area is in the Appalachian Plateaus Province. The surface is characterized by broad, sublevel divides, and valleys that are commonly narrow, especially the lower 200 feet. The depth of the valleys ranges from 500 feet at the southwest to 900 feet at the northeast. The upland surface rises to the northeast, from 1,200 feet above sea level in Beaver and Lawrence Counties to 2,200 feet or more in western Elk County. The exposed rocks in this area are dominantly of Conemaugh and Allegheny age. The Conemaugh rocks are in the hilltops in the southern part of the area and the Allegheny rocks in the valleys. The Allegheny rocks form the hilltops in the northern part of the area and the Pottsville rocks rise to outcrop in the valleys.

The Conemaugh rocks are all of minor economic value, mostly shale, sandstone, and thin limestones, coals, and clays. The sandstones have local value for structural purposes, the shales and clays for making brick and tile.

The Allegheny group contains most of the workable coal, some clay, sandstone, a little limestone, and much shale. Seven coal beds are locally workable, the Upper and Lower Freeport, the Upper, Middle, and Lower Kittanning, the Clarion, and the Brookville. Of these the Lower Kittanning is the most persistent, though the Upper Freeport may contain as much coal; the Lower Freeport is variable and may be a double bed. The Middle and Upper Kittanning are generally too thin to work at present prices. The Upper Kittanning carries cannel coal in several places, with a maximum thickness of 16 feet. Of the clays, the most valuable bed is under the Lower Kittanning coal. This is locally 15 to 20 feet thick and in places carries some flint clay. The clay under the Upper Freeport is next in importance and it too carries flint clay locally. The Vanport limestone is usually in two parts, the lower sandy, suitable for concrete aggregate or structural purposes, the upper part very pure and highly suited for flux, cement, and chemical lime. This limestone ranges from 2 to 20 feet in thickness and is lacking in considerable areas.

The Pottsville group includes the Homewood and Connoquenessing sandstones and the Mercer beds between them. The Homewood is variable but where massive, is suitable for building stone and glass sand. The Mercer member contains, locally, workable coal, thin limestone, some iron ore, and high-alumina clay. The Connoquenessing sandstone is commonly massive and underlies much of the high land.

Besides the coal, clay, limestone, and sandstone, all of which are produced on a fairly large scale, this area includes many square miles of oil and gas fields. Their output has brought oil refineries and industries using natural gas to the area. Rock salt in thick beds in the Salina formation of Upper Silurian age underlies much of the area at depths of 3,700 to 7,400 feet.

Upper Allegheny Area and Lake Erie Shore. All of the northwest part of the State is in the Upper Allegheny Area. It is a combination of plateau and a slope leading down to the ice-cut basin in which Lake Erie now lies. The plateau portion is level or rolling and rises with fair regularity from 1,100 feet near Sharon at the western State line to 2,200 feet in northeast Warren County and 2,400 feet in northwest Potter County. The lake basin slopes gradually from the edge of the plateau to 573 feet at the level of Lake Erie. Adjoining Lake Erie are several broad terraces separated by low escarpments recording former higher levels of the lake surface. At the west the streams generally have shallow valleys, except where the lower courses are becoming base-levelled at the lake surface and are cut back in deep "gulfs." At the east the valleys are mostly narrow and 400 to 800 feet deep. Some of the larger valleys that formerly drained toward Lake Erie, and now to the Allegheny River, are partly filled with glacial deposits and so have flat floors.

The Pottsville sandstone caps the upland throughout the south half of the area. Small patches of the Allegheny group rise above the general level on many of the divides. The middle Pocono caps the hilltops across the center of the area, and projects south up the valleys between the Pottsville-capped hills. The upper, more massive part of the Pocono was removed in the post-Mississippian-pre-Pennsylvanian interval. The middle Pocono now consists of the Shenango group of three sandstones and intervening shales, 150 feet thick (capped in places on old pre-Pennsylvanian-land-surface divides by Patton red shales); the Cuyahoga shales and sandstones, 150 feet thick; and the Berea, comprising the Corry sandstone and the Cussewago sandstone and shale, 100 feet thick.

Below the Pocono and cropping out along the slope facing Lake Erie, are strata of Upper Devonian age. These consist of beds formerly called the Catskill, Chemung, Portage and underlying strata. Today, these are designated in the northwestern part of the State as shown on the chart of oil and gas sands in the section on Oil and Gas.

The mineral resources of this area are primarily oil and gas. The bulk of oil still in the ground in Pennsylvania is believed to be in this area, as indicated in the Oil and Gas section. From east to west the oil occurs in successively higher and younger strata. In McKean County the oil comes from the Bradford and underlying sands, in Warren County from the overlying Warren sands, and in Venango County from the still higher Venango sands. Most of the oil comes from about 20 sandstones ranging in thickness from a few feet to 100 feet spread through about 1,800 feet of strata, all of Upper Devonian age. Gas has been obtained in many parts of this area from the Oriskany sand and a little from the Medina sand. A well in the extreme northwest corner of Erie County encountered the St. Peter sandstone of Lower Ordovician age, the one place in the State where it is known to occur. Small quantities of gas have long been gotten from the so-called Portage shales in the belt close to the shore of Lake Erie at about 1,000 feet below the level of the lake.

Coal comes second in the resources of this area. The coals are of Pottsville and lower Allegheny age and as a rule are mined only on a small scale for neighborhood use or for trucking to nearby areas. The coal beds occur only in the hilltops. In Mercer County the Brookville or Pardoe coal is mined and also stripped extensively where it is 3 to 4 feet thick, but in general the Pottsville beds are overlain by fairly massive sandstone that would not be favorable for stripping. The beds as a rule are thin and dirty. There may still be some mineable coal in McKean County.

Sandstone is abundant throughout this area; some of it, such as the Corry, is of good quality; much of it is conglomeritic, with pebbles up to goose-egg size. The Homewood sandstone is locally suited for use as glass sand. Clay and shale are both abundant, though not of as high quality as in the Lower Allegheny Coal Area. The larger part of the area northwest of Allegheny River and in Warren County was covered with glacial sand and gravel, and deposits are abundant throughout the area. In or adjoining the glaciated part of the area, is a considerable acreage of outwash gravel and gravel trains carrying large volumes of waters.

High Plateau Area. The High Plateau Area includes the "North Tier" counties from Potter to Wayne and high, flat land on both sides of the Northern Anthracite field. Topographically, it is characterized by high, level-topped plateaus held up by massive Pocono sandstone at the base of the Mississippian and massive sandstones at the top of the Devonian. These are preserved in synclines and form long fingers, usually quite broad, pointing north of east, and may carry a few hundred feet of the overlying Coal Measures, mostly in areas so small as to have little or no importance. Between these projecting fingers anticlines have brought up the underlying Devonian rocks, most of which are much softer and have worn down to much lower levels. Toward the northeast corner of the State the folding becomes less pronounced, except the infolded Northern Anthracite field, leaving a broad, high plateau — the Pocono Plateau south and east from the Northern Anthracite field,—and an equally broad but much lower and less even upland at the north and east, but in the Devonian rocks. This lower Devonian plateau spreads over Wayne and Pike Counties, being cut off from the higher plateau by an escarpment which drops sharply from 2,100 to 1,200 feet above sea level. The Northern Anthracite field is guarded by the up-turned edges of the Pottsville and Pocono sandstones that underlie that basin. These rise to 2,200 feet and even to 2,650 feet where they come together in Mt. Ararat in Wayne County.

This area has a minimum of mineral resources. A considerable quantity of natural gas was found in the Oriskany sandstone in Tioga and Potter Counties but is believed to have been completely exhausted in Tioga County and partly exhausted in Potter County. Small quantities of gas have been found in various parts of the area and, doubtless, many small pockets still exist. It is not impossible, though unlikely, that some large pockets may be found. An endless amount of sandstone exists, though none of it has been noted as suitable for shipping for fine structural work. The district has, in the past, had a large trade in flagstone. Flagstones for sidewalks have given way to cement, but they are still used in gardens, courts, porches, and floors of public buildings. Some of the sandstone has been used for glass. Red sandstone of the Devonian has been used locally and red quartzite in the Mauch Chunk formation has long been quarried for curbing, paving blocks, and crushed stone. Red shales are abundant for brick and tile. Clays are generally wanting, except in the small areas of Coal Measures or in glacial deposits. A little iron ore has been found in places throughout this area but none that has any financial interest at this time. All of the eastern portion of the area has been covered by glacial ice which changed the courses of many of the streams, resulting in numerous fine waterfalls, and a great many small glacial lakes and ponds. These features and large forested areas have made the eastern end of the area a popular vacation land. Camping, fishing, hunting, and winter sports are provided.

Endless Mountain Area. A region in the north-central part of the State is here called the Endless Mountain Area. It is an extension of the Allegheny Mountains Area but differs in that the basins enclosing coal-bearing rocks are much higher and smaller. It differs from the High Plateau Area at the north in that the coal basins here are lower, broader, and contain more coal. It differs from the Ridge and Valley Area to the south in containing only late Paleozoic rocks and is much less folded. The relief is pronounced. The massive sandstones at the base of the Mississippian and top of the Devonian lie high, rimming shallow basins in which some Coal Measures have been preserved. The intermediate broad anticlines bring up the softer underlying Devonian beds, which have been cut down into relatively hilly lowlands or into deep valleys. The bottoms may be as much as 1,800 feet below the adjoining uplands, the most striking topographical contrast anywhere in the State. Because of this, the area is largely given over to forests, fishing, and hunting.

The Coal Measures basins, though small, have been important, including the Renova, Tangascootack, Pine Creek, Ralston, Blossburg, Barclay, and Bernice fields. The coal in these fields is bituminous, excepting the Bernice semi-anthracite field. The beds are lower Allegheny and Pottsville in age and include the Marshburg, Clermont, Alton, Blossburg, and other beds. The massive Pocono sandstone and others are suitable for rough structural work and, doubtless, locally would be suitable for dressed building stone. Both soft and flint clay occur in the Coal Measures, especially in Clinton County, and are used for making refractory products. Some of these deposits have been abandoned because the clay was exhausted or because of the high iron content. The latter should be reexamined for high-alumina clay for making aluminum. Shales suitable for making common and face brick and tile could be found.

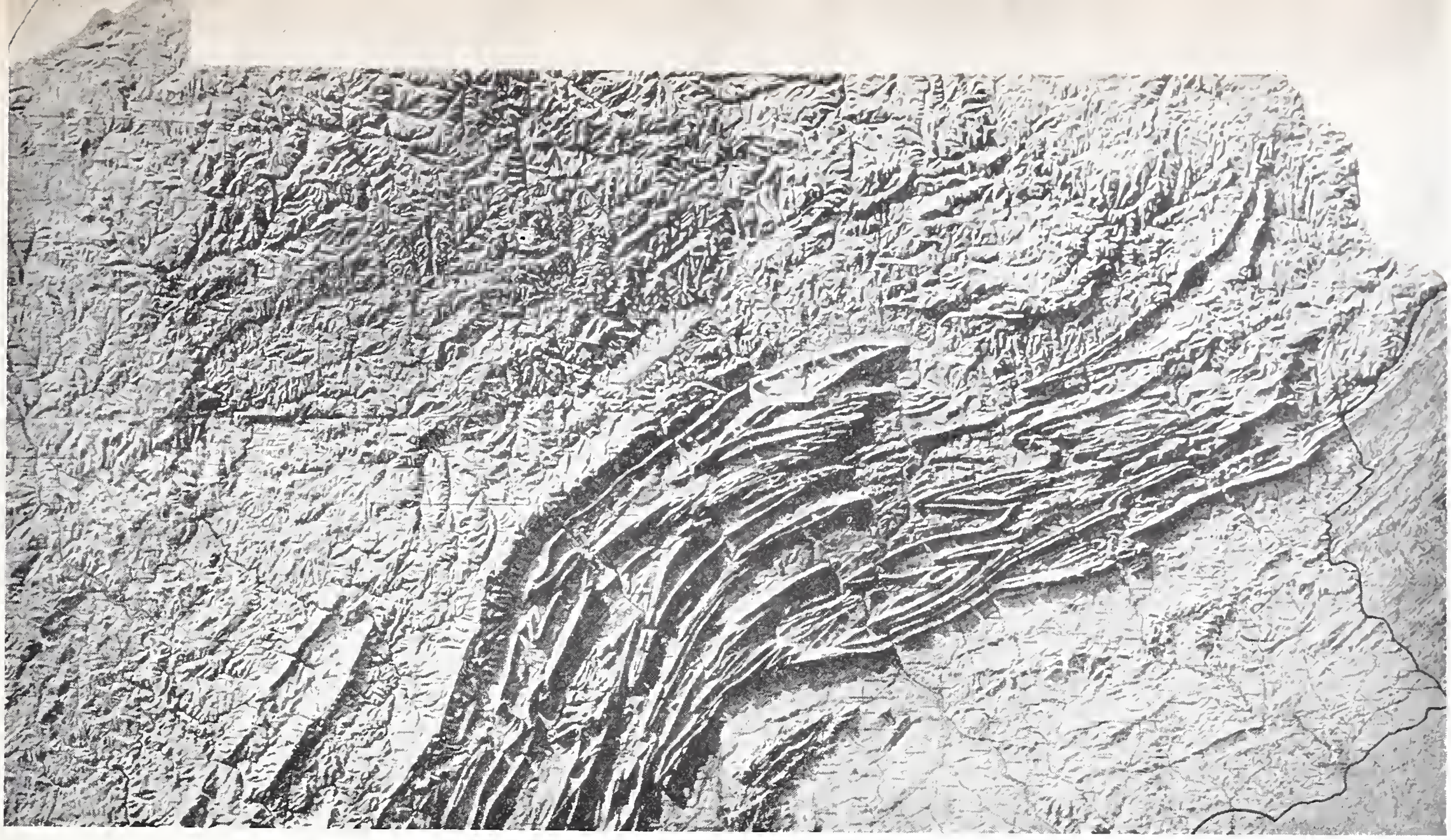

FIGURE 14. RELIEF MAP OF PENNSYLVANIA

COUNTY DESCRIPTIONS

By GEO. H. ASHLEY, RALPH W. STONE, R. M. FOOSE, and M. N. SHAFFNER

ADAMS COUNTY

Area 526 square miles. Population 39,435

Adams County, on the south State line, centered on Gettysburg, the county seat, is mostly in the Triassic Area. The north and west edges are in the Appalachian Mountain Area. In the southeast corner is an outlier of the Piedmont Highland of about one square mile and several square miles of the Piedmont Lowland. Agriculture and horticulture are important industries. The apple and cherry orchards centering about Biglerville are famous. The mineral industry is mostly the production of limestone flux and roofing granules. Railroad transportation is provided by three systems. U. S. Routes 15 and 30 traverse the county, which has 396 miles of improved State highways.
plain about 550 feet above sea level, with slightly entrenched stream channels. Several knobs, unreduced

Topography. Most of the county is a gently rolling remnants of trap rock, rise above the general level of the plain. The Pigeon Hills in the southeast rise to 1,046 feet. South Mountain in the north and west parts of the county has summits from 1,600 to 2,100 feet.

Rocks. Pre-Cambrian metamorphosed basalt and rhyolite of unknown thickness make the center of South Mountain. Flanking them on the west, the basal Cambrian quartzites and sandstones, 2,000 or more feet thick, are responsible for the highest parts of the mountain. Overlying them is an unknown thickness of Tomstown dolomite in the northwest corner and possibly 1,000 feet of Conestoga limestone in the southeast corner. The rest of the county is underlain by Triassic rocks, chiefly red, 23,000 feet thick, consisting of shales, sandstones, conglomerates, fanglomerates, and metamorphosed shale, and intruded by diabase or trap rock.

Mineral resources. The Triassic diabase has furnished building stone, crushed stone for concrete, and dressed stone ("Gettysburg granite"). It is very abundant and both fine- and coarse-grained. Baked shale adjoining the trap rock is used for road material. The Triassic brown sandstones have been used extensively for buildings and a few bridges. Residual clay from the limestone and some of the Triassic shales is worked for brick and tile, as southeast of New Oxford.

Limestone and dolomite are quarried extensively for flux and lime near Bittinger; the limestones in general are suitable for road material, concrete, and rough building stone. The high-grade lime produced is used for finishing wall plaster and in paper manufacture. The high-calcium limestone and white marble may have future special uses.

Roofing granules are made in the southwest corner of the county from metabasalt (greenstone). All materials mentioned thus far are abundant.

Brown iron ore occurs at the contact of quartzites and overlying limestone in the northwest and southeast corners of the county and at the foot of the Pigeon Hills. Some of the large deposits of high-grade ore were mined extensively in the previous century. Although some workable deposits of brown iron ore may remain, they are believed to be so sporadic that they have little present value.

Magnetic iron ore occurs between diabase and limy conglomerate near Cashtown and Idaville in beds about two feet thick and was mined for many years in the middle of the 19th century. Perhaps systematic drilling at favorable spots would disclose other and perhaps larger bodies of magnetite.

Quartz veins are more plentiful in the extreme northwestern part of the county than elsewhere and have been quarried there for silica used in crockery and tile manufacture. Quartz was formerly quarried one mile north of Cashtown. The large veins near Wenksville, Idaville, and Gardners offer possibilities for production of abrasive material or silica, if the iron content is too high for use in crockery.

Sand and gravel occur in the flood plains and on benches along many of the streams, especially those within and issuing from South Mountain. They are dug only for local use. Quartz sand derived from the weathering of Cambrian quartzite in South Mountain, if in commercial quantity, might deserve attention.

Some of the igneous rocks in South Mountain are attractive when polished and might be used for pen stands or other small ornamental articles. Native copper, asbestos, and whetstone occur in South Mountain, and garnet north of Fairfield, but it is yet to be proved if they are present in commercial quantity.

ALLEGHENY COUNTY

Area 730 square miles. Population 1,411,539

Allegheny County, centered on Pittsburgh, is probably the greatest industrial county in the United States, if not in the world, not counting food and clothing. Responsible factors (1) Junction of navigable rivers giving transportation to the whole Mississippi basin and to the sea. (2) The thick Pittsburgh coal bed of fine quality in and adjoining Pittsburgh. (3) Early settlement of the area and early start in the manufacture of iron, glass, etc. The south half of the county is in the Pittsburgh Coal Area. The north half in the Lower Allegheny.

Topography. The county is characterized by narrow, steep-sided valleys and rolling uplands 500 to 600 feet above the rivers. The Ohio River at Pittsburgh is 700 feet above sea level, and the hilltops are 1,250 feet above sea level in the southern half of the county and 1,300 feet in the northern half. There are broad terraces of preglacial rivers about 200 feet above present drainage. The narrow valleys are not ideal for town sites or industrial sites.

Rocks. Rocks of the Washington group cap the hills in the south end of the county. The Monongahela group flanks the valleys, rising to the north to the hilltops in the latitude of Pittsburgh. The Conemaugh group underlies the northern half of the county. Half of it is above water level at Pittsburgh. The Allegheny group rises above the Allegheny River at New Kensington and above the Ohio River at the county line. The Pittsburgh coal bed is extensively mined in the south half of the county and in the northern half the thick Freeport coal underneath Conemaugh rocks is being mined from a large area.

Mineral resources. The mineral resources are coal, natural gas, oil, clay and shale, limestone, sandstone, sand and gravel. A large part of the county's industry depends on "imported" mineral resources. Indeed, today the bulk of the coal used in the county is imported from other counties or States. The same is true of natural gas, oil, limestone for cement or flux, stone for building, and metallic elements for ferroalloys. Some of these imports are very large; for example, 13 million tons of iron ore (1937). Probably most of the 18 million tons of coal required for by-product coke made in the county in 1941 was imported from other counties—Washington, Greene, Westmoreland, and Fayette—so it may be truly said that Allegheny County's industrial preeminence, although originally built on her own mineral resources, today largely depends on minerals from other areas.

Coal. Two coal beds dominate the coal reserves of the county. Of the original 1¼ billion tons of Pittsburgh coal, about 250,000,000 tons are left for recovery. Of the 1¾ billion tons of Upper Freeport coal, it is estimated that about one billion tons remain. Coal beds below the Upper Freeport and above the Pittsburgh will doubtless add many million tons.

Natural gas. The second most important mineral in the county is natural gas. It has played a large part in the industrial growth of the county since 1883. The supplies today are greately reduced. Old pools are used as reservoirs for the summer storage of gas from other counties. Notable was the Haymaker well in the Murraysfield pool in 1878 from which an estimated 20 to 30 million cubic feet a day flowed for five years. The McKeesport gas pool, 1919, whose pioneer well reached 62 million cubic feet per day, started a memorable boom.

Oil. Some of the early pools in this county were large. The McDonald Field had many wells yielding 200 barrels an hour or more. Production has declined, however, and in recent years it has averaged only about 250,000 barrels per year. It has been hoped that the use of coring and the introduction of repressuring methods would reveal large reserves of oil and lead to increased production. Without repressuring, the life of the fields in the county is estimated at 10 to 20 years. Repressuring and continuing the recent rate of production may prolong them to 100 years or more. Actually, repressuring would probably greatly increase the annual production, and to that extent reduce the life of the field.

Clay and shale. The better clays and shales of this area are in the Allegheny formation, which crops out only along the northern edge of the county, but they underlie all of the county and can be obtained anywhere by shaft mining. These clays and shales are the basis of the large ceramic industry of Beaver County. The shales of the Conemaugh are much used for building brick and tile, in the manufacture of which Allegheny County stands near the top. Certain clays are suitable for the less refractory type of fire brick.

Limestone. Limestone is abundant in the county, but most of it is impure and not suitable for chemical lime, flux, or cement. Some of the limestones, notably the Benwood, are suitable for agricultural lime, road metal, and railroad ballast. The county stands third in the State in the making of cement, but imports limestone for that purpose.

Sandstone. No high-grade sandstone for building purposes is known in the county, but a number of the sandstone beds yield stone suitable for foundations, bridge abutments, and other such uses. Such sandstone is abundant.

Sand and gravel. Sand and gravel is abundant in the bottom of Allegheny River and in the old river terraces as high as 200 feet above the river. Sand can be produced by crushing many sandstones in the county. These sources are probably adequate to supply the county's needs for many years.

Salt. Salt was once obtained near Tarentum from salt wells, the brine coming from 400 feet below the Upper Freeport coal or in the middle Pottsville. Rock salt is known to occur in the Salina formation of Upper Silurian age, and has been penetrated in a well at depths of more than 7,000 feet. Whenever it may be profitable to obtain brines from this depth, it seems certain the reserves are extensive.

ARMSTRONG COUNTY

Area 660 square miles. Population 81,081.

Armstrong County corners with Allegheny County, lying east of Butler and north of Westmoreland. It is all in the Lower Allegheny Coal Area. The valley of Allegheny River crosses the western part of the county from north to south, and with its tributaries provides low-grade transportation through the county. The chief mineral resources are coal, clay, sandstone, limestone, oil, and gas. There are large reserves of the first four. If secondary recovery methods are used, oil may be produced at the present rate for a long time. Gas reserves are not large.

Topography. Armstrong County is in the plateau country. The Kellersburg and Greendale anticlines in the western and eastern parts of the county create low, broad uplands, 100 to 200 feet above hilltops which average 1,300 feet above sea level. In the northeast corner of the county, the hilltops rise to 1,600 feet. The Allegheny River and its tributaries make gorge-like valleys 250 to 300 feet below the general hilly upland in the western part of the county.

Rocks. The Monongahela group with the Pittsburgh coal at the base forms the crest of Elders Ridge along the southeast edge of the county. This group underlies a small synclinal area. The Conemaugh group covers the upland over most of the south half of the county, and the principal valleys in that area cut down into the Allegheny group. In the northern part of the county, especially in anticlinal areas, the Allegheny rocks with their coals and clays rise to the hilltops, and the valleys expose Pottsville rocks. The Vanport limestone is well developed at its horizon. The Mauch Chunk is lacking in this county unless it occurs in the extreme south end. The Pocono formation is exposed in Allegheny Valley above Mahoning.

Mineral resources. The mineral resources of Armstrong County are coal, clay, including flint clay, limestone, sandstone, oil and gas, sand and gravel, glass sand, and molding sand. Of an original 4,120 million tons of coal, 220 million tons have been mined out and lost. Reserves include 920 million tons in beds more than 3 feet thick, 355 million tons in 2 to 3 feet beds, and 1,315 million tons recoverable from beds less than 2 feet thick. The Pittsburgh bed is considered to be exhausted. Most of the coal remaining is Lower Kittanning, Upper and Lower Freeport. In the south half of the county, the Upper Freeport is 2 to 5½ feet thick with generally one or two partings near the bottom, though many sections show solid coal. The Lower Freeport as usual is variable, ranging up to 6 feet thick. Locally the coal is bony and high in sulphur. The Lower Kittanning coal, ranging from 2 to 5 feet, commonly has 6 to 10 inches of bone coal at the top. Some sections are clean, others have one or two partings. The Upper Kittanning coal locally fills channels and is as much as 16 feet thick. The Brookville coal has some importance in Mahoning Creek basin. Little is known about the lower coals in the southern part of the county.

An estimated 5 million barrels of oil are obtainable by present methods at present prices if secondary recovery is used. Without secondary recovery the amount will be perhaps one-tenth. At 20,000 barrels a year, the field will not last more than 25 years without secondary recovery methods.

Clay and clay products come next to coal in value. The Mercer clay is not well exposed in the county; it is 8 to 10 feet thick where mined on Redbank Creek along the north county line. Analyses showed 38 percent aluminum oxide. The Clarion and Lower Kittanning clays, the former from 8 to 10 feet thick, are being mined at Kittanning and elsewhere in the county for brick, tile, and pottery. Some flint clay occurs at the Clarion horizon. Clays appear to be widespread and of good quality throughout the county. While locally the Lower Kittanning clay is 12 feet thick, it appears to be less regular and of lower quality than the Clarion clay. Upper Freeport clay is widespread and ranges up to 6 feet in thickness. Some of it is flint clay. Shales for making brick and tile are abundant and are used with underclays at many places.

The Vanport and Upper Freeport limestones occur throughout the county. The Vanport, ranging from 8 to 22 feet thick and averaging 93 to 96 percent calcium carbonate, has been used for cement making, flux, and lime. The Upper Freeport limestone, 28 feet thick near Ford City, but generally much thinner, has from 84 to 96 percent calcium carbonate.

The Saltsburg sandstone has been extensively quarried for dimension stone. Locally the Freeport and Homewood sandstones have been quarried for the same purpose. These sandstones and the Mahoning sandstone have all been crushed to sand for grinding glass at the Pittsburgh Plate Glass Plant at Ford City.

In early days iron ore was mined extensively in the county at the "Buhrstone ore" horizon at the top of the Vanport limestone. The ore was six inches thick and carried 33 to 38 percent iron. The brown and red ore formed by oxidation of the carbonate carried up to 50 percent iron. Ore also has been mined from the horizon of the Upper and Lower Freeport coals. This carries less iron than the Buhrstone ore.

BEAVER COUNTY

Area 441 square miles. Population 156,754.

Beaver County is on the west boundary of the State. The Ohio River flows through it and it is near Pittsburgh. These facts enhance its value as a mining and manufacturing county. It lies entirely in the Lower Allegheny Coal Area, which means that it has practically no Pittsburgh coal; only Allegheny and Pottsville coal beds. These coals are generally fewer and thinner than farther east. The Homewood and Connoquenessing sandstones have been extensively quarried and shipped. Clay mining and clay industries have been extensive. River transportation and excellent railroad facilities have made Beaver County the center of a large iron and steel industry. It contains oil and gas. Industries include oil refining, glass making, zinc refining, and the making of alloys, all on a fairly large scale.

Topography. The fairly broad hilltops are between 1,200 and 1,300 feet above sea level throughout the county. Moderate to steep slopes descend 100 to 300 feet to the valleys, which are generally narrow but locally wide, owing to drainage changes associated with the glacial invasion. The Beaver River is about 730 feet above sea level at Beaver Falls, and the Ohio River is about 670 feet at the mouth of the Beaver. Broad gravel-covered benches at 900 feet and lower are remnants of old valley bottoms when the whole area drained northward by way of Beaver and Mahoning Valleys to Lake Erie basin. After glacial ice closed that outlet and turned the drainage down the present Ohio River, main channels were deepened and later partly filled with outwash gravel to its present level.

Rocks. The Pittsburgh coal underlies few small hilltops. Nearly all of the upland is underlain by the Conemaugh group, about 600 feet thick, consisting of shales, sandstones, thin coals, and limestones, having little immediate economic value. The rocks rise northward, bringing the Allegheny group to the top of all but the highest hilltops along the north boundary of the county. The same rocks make up the flanks of the hills and descend to river level where the Ohio River enters the county. The Allegheny group contains coal, sandstone, clay, and limestone of value. The Pottsville and some of the lower Allegheny rocks occupy the channel and lower valley of Beaver River and of the Ohio channel to several miles above the mouth of Beaver River. Glacial deposits blanket the northwest corner of the county.

Mineral resources. In approximate order of reserves, the county's mineral resources include sandstone, clay, coal, sand and gravel, oil and gas, and limestone. The Homewood and Connoquenessing sandstones are massive and well suited for heavy structural work. The Homewood is of good quality over a considerable area in the northern part of the county, but is replaced by shale elsewhere. The Connoquenessing sandstone is more persistent, but lies lower in the hills and as a rule is not as well situated for quarrying.

Clay. Most of the clays suitable for commercial use occur in the Allegheny group. These are: Upper Freeport clay, 3 to 5 feet thick; Lower Freeport clay, 3 to 5 feet thick; Middle Kittanning clay, 4 feet thick; Lower Kittanning clay, 1 to 11 feet thick. The last is the bed principally mined. It generally has 4 to 6 feet of good plastic clay above a variable thickness of sandy clay. Its position low in the hills just above the railroad level along the Ohio and lower Beaver Rivers is favorable for its development. Leighton estimates a potential supply of nearly a billion tons of clay within 1½ miles of the outcrop. The quantity must be very large, including that below river level in the southeast part of the county. The Upper Freeport clay is reported to be 10 to 22 feet thick at Fallston, and 14 feet thick at Georgetown. The Lower Freeport clay is 14 feet thick on Blockhouse Run. The Clarion clay is said to be of high quality, but it is exposed at few places and has been little explored. Shales are abundant throughout the county, but are little used.

Coal. Excepting the Upper Freeport, the coals of the county are all very thin. Three feet is exceptional. The Middle and Lower Kittanning are persistent and range from 14 to 40 inches, often without partings, but usually with one or more thin partings. The Upper Kittanning coal is locally of cannel type and up to 13 feet thick. Generally it is less than one foot thick. The Lower Freeport coal ranges from 1 to 3 feet thick. The Upper Freeport is the most important coal in the county, ranging from 1 to 7½ feet and averaging 3 or 4 feet. In Darlington Township a coal, the "East Palestine" (Brush Creek), 70 feet above the Upper Freeport, ranges up to 4 feet thick over a small area.

Oil and Gas. Oil was found in Beaver County at Smiths Ferry in 1860. The early wells ranged from 72 to 180 feet deep. The county has never been a large oil producer, though in 1890 it reached a production of almost 1½ million barrels. Since then it has declined more or less steadily until in recent years the production has ranged between 30 and 40 thousand barrels. Production has come mostly from the Berea sand, which lies about 700 feet below the Middle Kittanning coal. Beaver County has also long been a small producer of natural gas. Twenty years ago the production was between 300 and 400 thousand cubic feet. Recent drilling to the Oriskany sand has developed some additional gas. The Oriskany sand is between 4,600 and 4,800 feet below the Lower Kittanning coal. The white Medina sand is 2,000 feet deeper.

Limestone. The Vanport limestone, though named from a point in this county, is thin and worthless at most places as far as known. It reaches a thickness of 15 to 20 feet at Vanport and Ellwood City and has been mined. In many areas it is only 1 foot thick; locally it is 8 feet or more. It is of high quality where tested. The Lower Freeport limestone locally is 3 to 9 feet thick, but in general it is too thin to mine. It is not as pure as the Vanport. The Upper Freeport limestone is usually impure and thin, but locally it is 6 to 7 feet thick.

Sand and gravel are obtained both by dredging in the river and by digging in terraces and glacial deposits. Sand is also obtained by crushing the spalls from sandstone quarrying at Koppel.

BEDFORD COUNTY

Area 1,018 square miles. Population 40,809.

Bedford County lies in the Ridge and Valley Area. The rocks of the county have all been strongly folded. The highest ridges up to 3,100 feet above sea level, are held up by the resistant Silurian Tuscarora sandstone, Mississippian Pocono sandstone, and Pennsylvanian Pottsville sandstone; others by the Devonian Oriskany sandstone. The valleys are underlain by soft shales, especially in the eastern and western parts of the county, and by limestones in the central part. The Broad Top coal basin is situated in the northeastern corner of the county. The metallic resources of the county include the ores of iron and manganese, and the non-metallic resources include coal, limestone, sandstone, ganister, clay, and shale.

METALLIC ORES

Iron ore. Iron ore occurs to a greater or less degree in all the formations exposed in Bedford County. Some of these ores were mined and smelted locally in the first half of the 19th century.

Clay iron-stone occurs under the Barnett coal bed in the Broad Top coal field; it is not known to have been prospected, and it probably has little economic value. Brown hematite is present in the Mauch Chunk within a few feet of the bottom of the formation. This ore was mined and smelted at Hopewell. Its occurrence was noted at several places in Ground Hog Valley in Broad Top Township where iron and manganese oxides occur together. Brown hematite is associated with the Pocono, but commercial quantities are doubtful. Scattered fragments of brown hematite from the Chemung were noted on the hillsides in some localities, notably on the hills west of Buffalo Mountain, southwest of Saxton, and at places in Monroe and Southampton Townships; workable deposits are not known.

The brown hematite ores in the lower Helderberg were mined extensively at two places on the west side of Warrior Ridge in Hopewell Township. This ore was smelted in the furnaces on Yellow Creek. Extensive operations were also carried on west of Everett. Fair deposits of ore were reported from other parts of the county.

The Clinton formation contains the important iron-bearing horizons in the county. Ore is variably present in three beds called the Fossil, Frankstown, and Block ore beds. The Fossil bed is the important one of the group and has been mined extensively at numerous places; its best development was reported to be in Black Valley between Tussey Mountain and Warrior Ridge. In Cumberland and Londonderry Townships the Fossil ore is a single bed averaging 14 to 18 inches thick. In other townships the ore is in two or three beds, the thickest of which is three feet. The available ore in all three beds, however, is about two feet.

The soft surface ore carries 45 to 58 percent iron. The ore at depth is hard and of lower grade.

Because of the extensive outcrops of the Clinton formation from north to south across the county, it is presumed that reserves of ore in this bed are large. The Frankstown bed is about 380 feet below the Fossil bed; its known occurrence is on the west side of Dunning Mountain and on the east slope of Wills Mountain. This ore has doubtful economic value. The Block ore is at the base of the Clinton formation. The bed has had but minor development in the county, although good deposits were reported in West Providence Township and Juniata Gap through Evitts Mountain.

Manganese. The basal fifty feet of the Mauch Chunk red shale commonly bears the oxide ores of manganese and iron throughout the county. At one place, in Sherman (Ground Hog) Valley, south of Hopewell and east of Wells Tannery, manganese ore occurs in concentrations approaching commercial importance. Most of this area has been carefully investigated;[1] however detailed mapping of the entire valley may be worthwhile. On the Simon property the ore has been partially developed and a small amount of high-grade ore was shipped in 1942. The ore is an irregular, tabular replacement of the bedding. Therefore, reserves are contingent upon its continuity down the dip toward the northwest and along the strike. A minimum of careful exploration by drill holes down to the underlying Pocono sandstone would determine any reserves.

NONMETALLIC RESOURCES

Limestone. There are abundant reserves of limestone in this county. Most of the Morrison Cove in the north-central part of the county, and Friends Cove (Snake Spring Valley), between Everett and Bedford are underlain by Cambro-Ordovician limestone. In narrow bands, the Devonian Helderberg limestone crops out or underlies considerable areas parallel to the northeast-southwest trending ridges.[1] There are quarries all over the county, but only three operations of large size. The quarries produce some building stone, a large amount of fluxing stone and of crushed stone for road metal and construction purposes, and considerable agricultural limestone and stone for lime products. Only a few very pure beds in the Helderberg limestone approach consistent high-calcium content.

Sandstone. Northward from Everett the Oriskany sandstone makes a low ridge east of and parallel to Tussey Mountain. Along this ridge the sandstone has been and is being quarried at numerous places for glass sand and construction sand. It is locally very clean, white, and free from iron oxide. Doubtless there are other places in the county where the Oriskany can be successfully developed if careful examination by drilling precedes the operation.

The Tuscarora quartzite, which makes the crest of Tussey, Evitts, and Dunning Mountains, weathers to large blocks which have accumulated at many places along these ridges in rock floes. Much of this material is excellent ganister that would find use in the silica refractories industry. Locally it has been used for construction purposes.

The Pocono sandstone, holding up Rays Hill, and the Pottsville sandstone, making the high rim around the Broad Top coal field, are both commercially undeveloped. The Pocono might be used for building stone. Neither would be tough enough to have much value as crushed stone.

Shale and clay. Shales suitable for the manufacture of brick occur at many places in the county. The Catskill red shales of Upper Devonian age underlie a linear belt parallel to the Allegheny escarpment at the western edge of the county and surround the Broad Top area, being especially thick north of Breezewood. These shales have been successfully used for brick making.

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[1] Foose, R. M., The Manganese Minerals of Pennsylvania: Penna. Topog. and Geol. Survey Progress Report 128, 1942.

[1] Miller, B. L., Limestones of Pennsylvania: Penna. Topog. and Geol. Survey Bull. M 20, pp. 196-207, 1934.

The gray shales of the Middle Devonian are not as good for brick making as the Catskill shales. These shales underlie considerable area in both the east and west parts of the county. Commonly they are sandy and have little value for anything but road dressing. However, there are many zones of nonarenaceous shale which would be of value for making hollow tile, drain tile, common brick, and face brick.

The Ordovician and Silurian shales in the central part of the county are less promising, although it seems likely that some of the Reedsville shales, easily accessible in Snake Spring Valley, would be suitable for the manufacture of common brick.

White clay, residually accumulated by weathering of the Cambro-Ordovician rocks in the north-central part of the county, has been worked at one place near Baker Summit and used to make refractory cement for the steel industry. This clay is not present in very large quantities or over large areas, but it is of good quality.

MINERAL FUELS

Coal. The most important producing area of the Broad Top coal field lies in the northeast corner of Bedford County. Geographically, this field occupies a high dissected plateau, intermediate in position with respect to the bituminous fields in the west and the anthracite fields on the east. The coals in the Broad Top field have been mined for more than 100 years, but there are still considerable reserves. Based on the fuel ratio of the analyses, these coals fall into the class known as low volatile. The major structure of the field is a broad synclinal basin with the axis trending about N. 30° E. Within the major structure, there are numerous minor complex folds and faults which make mining exceedingly difficult.

There are approximately 13 coal beds, probably all of which are included in the Allegheny group. Three of the coals are mined commercially; they are in ascending order, the Fulton, Barnett, and Kelly. Many of the other coals have minable thickness locally. The Fulton coal is fairly persistent, ranges from three to five feet thick, and contains numerous shale partings. The Barnett coal maintains a workable thickness over large areas in the field; it ranges from three to four feet thick, has four to six inches of bony at the top, and is frequently divided into different benches by bone or shale partings. The Kelly coal, being higher in the series than the Fulton and Barnett, is more limited in area since more of it has been eroded. The bed ranges from three to five feet thick and is very persistent. Reserves of coal are estimated at 80 million tons immediately available, of which 65 million are in beds over 3 feet thick.

BERKS COUNTY

Area 864 square miles. Population 241,884.

Berks County lies south of Schuylkill and Lehigh Counties. The Schuylkill crosses it from north to south. Kittatinny or Blue Mountain, of Tuscarora (Silurian) sandstone, makes the north border. Much of the county is in the Great Valley, underlain on the north by the Martinsburg (Ordovician) shale and sandstone, and on the south by the Cambro-Ordovician limestones. The Appalachian Mountains Area, mostly pre-Cambrian, extends from the east corner to the center of the county. The south corner is in Triassic rock, except the tip. Reading is the county seat. Railroads and highways offer transportation facilities to all parts of the county.

Geologic formations exposed are pre-Cambrian and Triassic igneous and metamorphic rocks, Cambrian to Silurian, and Triassic sedimentary rocks. The mineral resources are ganister, crushed stone, brick, cement, iron ore, slate, clay, and building stone.

Ganister. The Chickies quartzite is quarried in South Mountain just over the line in Lebanon County and made into refractory brick one mile southwest of Womelsdorf. Rock of the same character occurs in many places in the Reading Hills and may be used for ganister or crushed stone.

Crushed stone. Trap rock and limestone are quarried and crushed extensively for concrete aggregate, road metal, and railroad ballast.

Trap rock or diabase crops out almost continuously across Spring and Cumru Townships to the Schuylkill, thence parallels the river just south of Birdsboro and Monocacy to the Chester County line. It occurs also along the Lancaster County line in Brecknock and Caernarvon Townships, near the Montgomery County line, and in hills in Exeter Township. The principal quarries are near Birdsboro and Monocacy, one of which can produce 3,000 tons of crushed stone daily.

Limestones underlie a broad belt on the south side of the Great Valley from Manatawny to Leesport, thence south to Reading and west to Womelsdorf. Another large area is in Oley Valley. Smaller tracts occur between Reading and Boyertown, and at the southern tip of the county. The principal quarries are near Kutztown, Evansville, Temple, Shillington, and Wernersville. The larger ones can produce several hundred to 1,000 tons of crushed stone daily. The main use of the stone is for concrete aggregate and road metal. Some is sold for railroad ballast. In former years limestone was quarried for flux in local iron furnaces, burned for lime, and some limestone was used for building stone. The stone ranges from massive to shaly and from high-calcium to dolomite.

Cement. The only portland cement plant in Berks County is at Evansville. Argillaceous limestone of the Jacksonburg formation, which overlies the Beekmantown limestone, is obtained from a large quarry. The stone is of various grades, but some well-defined bands of fairly uniform grade can be traced across the property.

Brick. The Martinsburg shale where somewhat weathered may be suitable for making brick. It was formerly used near Shoemakerville and is now used at Wyomissing for making face brick. The Martinsburg shale extends across the northern part of the county in a wide band.

Yellow and red plastic residual clay in the limestone areas may occur in occasional pockets large enough to work. Such clays usually are suitable for floor and art tile, various types of pottery, and in some cases for common or face brick. A small brickyard at New Berlinville uses yellow residual clay. Brick were once made at Kutztown.

The Triassic red beds in the southern part of the county should yield good brick shale in areas where the shale is soft.

Kaolin mined several decades ago about one mile southeast of Friedensburg, Oley Township, was used in weighting paper.

Slate. At the base of Kittatinny Mountain very near the northern end of the county, roofing slate was formerly quarried at Quaker City, 1½ miles west of Steinsville, Lehigh County. Reserves of high quality roofing slate probably are lacking. "Slate" produced in Oley Valley was used for lining lime kilns. Red and green "slate" near Lenhartsville was formerly ground for filler and pigment.

Iron ore. The first iron furnace in Pennsylvania was erected about 1720 on Ironstone Creek, three-eights of a mile west of Boyertown. The ore was a dull reddish black powder like soft magnetite. Pig iron was sent to England. Prior to the Revolutionary War, 11 forges in the county used local limonite.

Three kinds of iron ore occur in the county, magnetite, brown hematite or limonite, and red hematite. Magnetite has been mined in Longswamp, Hereford, Oley, Alsace, Washington, Colebrookdale, Earl, Ruscombmanor, and Cumru Townships, and within the city limits of Reading. Titaniferous magnetite occurs near the north corner of Pike Township.

Mining began in Longswamp Township before 1785 in Rittenhouse Gap. The ore was hard, siliceous, and carried 40 to 45 percent iron, but it was almost free from sulphur and phosphorus. Mining ceased in 1882.

One mile east of Seisholtzville, in Hereford Township, the better ore, carrying 45 percent iron, was a soft, black to brown powder. Hard ore encountered was too lean as it had only 22 percent iron.

Reserves of low-grade magnetite ore probably remain in the Rittenhouse Gap-Seisholtville district. Any proposed mining operation should be preceded by exploratory drilling. The results of geophysical tests by Federal agents have not been made public.

Boyertown is the site of the largest ore mines in the county. Hard magnetite occurs as a replacement deposit in Triassic limestone conglomerate at the contact with intruded diabase. Mining by slopes and shafts was done from 1870 to 1892 and large quantities of ore were removed from stopes. The blue ore averaged 34 per cent iron and the black ore averaged 44 per cent, with a maximum of 54 percent. The mines were dewatered in 1917 but no ore was mined.

With all data available in September 1943, close to a million tons of proved ore remains as reserve. Probable ore reserves, of course, would exceed this figure, especially if concentrating ore is included. Exploratory diamond drilling was done here in 1943 to prove sufficient tonnage for planning mining operations.

The Jones mine in Caernarvon Township, 3 miles northeast of Morgantown, opened in 1735 and closed in the 1880's, was another large producer. Information is lacking as to the presence of reserves.

Other magnetite mines, too numerous to describe here, are recounted in Second Geological Survey Report D 3, pages 237-352.

Brown hematite or limonite is more abundant than the magnetic ore. Wash and lump ore was mined prior to 1880 in Hereford Township near Seisholtzville; Oley Township, 1¼ miles northeast of Friedensburg; in Ruscombmanor Township 1¼ miles northeast and 1½ miles southwest of Pricetown; in Spring Township 1 mile northwest and 1¼ miles north of Shillington; and in Richmond Township one mile west of Moselem Springs. It remains to be determined where else it may occur. The best ore in the mines carried about 50 percent iron. Red hematite occurs in the Dotterer mine in Earl Township, 2 miles west from

Hill Church. It is the only mine in Berks County showing workable ore in massive, crystalline, steel-gray form of the specular hematite variety, and earthy, blood-red to brown ore. The ore is reported to be low in iron, high in silica and titanium, and so of questionable value.

Red and specular hematite have been found in Furnace Hill and in Rockland Township. Perhaps further search would reveal good ore in mineable quantity.

Building stone. Only three other counties surpass Berks in the variety of stone within her boundaries that can be used for building. Here are granite, gabbro, diorite, granodiorite, diabase, basalt, pegmatite, schist, limestone, slate, sandstone, quartzite, and conglomerate.

Granitic rocks and quartzite are mainly in the Reading Hills and South Mountain, and the largest granite quarry is at Seisholtzville.

Buildings of local stone are, for the most part, not far from their source; limestone in the valleys, variegated sandstone along the north border, brownstone in the southern part of the county. An abundance of material and a wide variety await those who wish to build with native stone.

Flagstone. Sandstones in the Martinsburg formation were found suitable for flagstone and quarried many years ago three-fourths of a mile northeast and two miles east of Shoemakersville, two miles west (?) from Kempton, and just north of Virginville. Probably more could be produced at these places and other quarries could be opened.

Graphite. Graphitic gneiss has been prospected 1½ miles southwest of Rittenhouse Gap, 2 miles south and 1 mile southwest of Longswamp, ½ mile northeast of Seisholtzville, and 1 mile northwest of Boyertown. Concentrating mills were erected near Longswamp about 1897 and Boyertown in 1899 and operated for a few years, but perhaps not profitably.

REFERENCES:

Second Geol. Survey, D 3, Part II, Summary Final Report 1892, Part I, pp. 235-38, 267-69, 350, 609-15.

Topog. and Geol. Survey Comm. Report No. 6, Graphite.

BLAIR COUNTY

Area 530 square miles. Population 140,358.

Blair County is in the central part of the State in the Ridge and Valley Area. Altoona, with a population of 80,214, is the only city. Hollidaysburg is the county seat. Tussey Mountain more than 2,000 feet high marks the east boundary, and Allegheny Mountain 2,500 feet above sea level, the west boundary. Between them is a limestone valley 1,000 feet lower interrupted by high narrow ridges of tough sandstone. Transportation is furnished by the main line of the Pennsylvania Railroad and several branches, by U. S. Routes 22 and 220, and 339 miles of improved State highways.

Rocks. The outcropping rocks range from the limestone and dolomite of Cambrian age to the basal Coal Measures. They are mostly limestone, sandstone, and shale. They have a general northeast-southwest trend, but plunging folds make great loops in Brush, Dunning, and Lock Mountains, and so in the outcrop of formations. Great faults also disrupt the regularity of the normal trend of the rocks.

Mineral resources. Lead, zinc and iron ore are present in the limestones. Today, the mineral resources are limestone and sandstone, clay and shale, and minor amounts of coal.

The first lead and zinc mines in Pennsylvania operated in Sinking Valley during the Revolutionary War. Later sporadic attempts to mine the ore met with indifferent success. The ore occurs in crevices in dolomitic limestone and consists mainly of sphalerite and galena. The main ore body was west of Birmingham Station. Considerable exploration seemingly indicates that the most favorable locality for prospecting for lead and zinc within the county is in the southern end of Sinking Valley.

Residual iron ores within the limestones were extensively worked in the county early in the 19th century. The Clinton fossil ore was opened at numerous places along its outcrop below the Helderberg limestone, but is generally thin and of little value. The brown iron ores associated with Cambro-Ordovician limestones have future economic importance. Sizable quantities of this ore were taken out long ago in the Bloomfield, Henrietta, Rebecca, Soister, and Springfield mines, and in mines in Canoe and Sinking Valleys. The ore occurs as lump and wash ore, mixed with clay, sand, and gravel. It is variable in character and very irregular. Analyses indicate an average of over 50 percent metallic iron.

Limestones occur in several geologic formations. The Cambro-Ordovician limestones underlie Sinking and Canoe Valleys at the north and northeast respectively, and Morrison Cove at the east and southeast. The outcrop of Helderberg limestone starts at the northern border of the county and follows along Little Bald Eagle Creek to beyond Hollidaysburg, where it makes a loop around Frankstown Township, and then follows the west flank of Dunning Mountain south. Because of the variability in chemical composition and physical characteristics of these rocks, they are usable for different purposes. Several quarries are working these limestones, chiefly for crushed stone and for agricultural lime. Reserves are large.

The Pocono sandstone occupies the upper slope of Allegheny Mountain. The Oriskany sandstone ranges from 20 to 50 feet thick. Its outcrop follows along the foot of Bald Eagle and Dunning Mountains. It is usually friable and decomposes into loose, sharp sand. Locally, it has qualities suitable for building stone and glass sand. The Tuscarora (Medina) sandstone is the prominent feature of the geology. The outcrop forms the crests of Bald Eagle, Brush, Canoe, Lock, Dunning, and Tussey Mountains. Great quantities of this rock are available in rock floes on the mountain sides, particularly on Bald Eagle Mountain. Large operations at Claysburg and Sproul are using this material for ganister.

The lower Coal Measures underlie two small areas on the top of Allegheny Mountain. They contain some workable coal and fire clay.

Residual clays, derived by weathering from feldspathic quartzites and argillaceous cherty limestones, occur in the Gatesburg formation and the Oriskany sandstone. These clays are being worked at various places in the county for refractory cements and linings in the furnaces in the steel industry.

Shales that may be used for brick manufacture occur in the Mississippian and Devonian rocks.

BRADFORD COUNTY

Area 1,147 square miles. Population 50,615.

Bradford County borders the New York State line for 40 miles, and is the third one from Delaware River. Towanda, with a population of 4,154, is the county seat. Sayre, the largest borough, has 7,569 people. A gateway from central New York has been cut through the county by Susquehanna River, which flows southeastward into Wyoming County. Railroad transportation is furnished by five systems. The Roosevelt Highway (U.S.6), U. S. Route 220, and other important highways traverse the county which has 621 miles of improved State highways.

The county is a deeply dissected portion of the Appalachian Plateau. The topography ranges from rolling and hilly to high and rough. The only remnants of the high plateau surface are in the southwestern part of the county, where Armenia Mountain on the west boundary is more than 2,300 feet above sea level. The altitude of large parts of the county is 1,200 to 1,500 feet.

The exposed rocks range from the Upper Devonian Chemung formation to the Allegheny formation of Pennsylvanian age. The coal-bearing rocks occur only in the synclinal remnants of the high plateau. The Chemung formation underlies several anticlinal valleys that traverse the county from east to west, and the intermediate slopes are underlain by Catskill rocks.

The entire county has been glaciated and the bedrock, therefore, is covered in many places by glacial drift.

The geologic structure is typical of the Plateaus province. Several anticlines and synclines are included within the county. Their axes trend northeast and north of east, as do the faults. Dips are gentle.

MINERAL RESOURCES

The mineral industry is small, consisting of a few flagstone quarries along the Susquehanna, some crushed stone, bank sand and gravel, and a little coal.

There are no metallic minerals in the county that would merit more than mineralogic interest. Manganese oxide, usually in the form of wad, a soft black material, may be found in small quantities at many places associated with the Chemung and Portage sandstones, and in the southwestern part of the county with the Pocono sandstone. On small plateaus, bog ore frequently occurs at the site of an old spring or in an undrained depression. Some of this bog ore may have economic value for gas purification. Copper carbonates occur as thin films on joint and bedding planes in the Devonian rocks near New Albany. A thin band of chalcocite has also been observed in these rocks, but there is nothing of value.

Stone. The Pocono and locally the Pottsville sandstones have been quarried for building stone. In the southwestern part of the county these rocks could be quarried wherever they crop out.

Flagstone has been the most important rock product in the past. In the vicinity of Towanda and Wysox, and near LeRaysville excellent flagstones with a wide range of thickness and rectilinear dimension have been quarried from the Devonian sandstones. Some of these quarries, which have been abandoned, would merit being reopened if the market for flagstone demands it. It is also reasonable to assume that new quarries could be opened at other places in the Devonian sandstones.

Limestone occurs locally in the Chemung rocks. About a mile east of Burlington the stone was once burned for agricultural lime. North of Wyalusing some limestone has been crushed for road metal. However, the county limestones probably will have no economic value for many years. All parts of the county are too easily accessible to good imported limestone products.

Some of the tougher Pocono and Devonian sandstones could be crushed for road metal. However, none of them would make first-grade, crushed stone.

Sand and gravel. Some sand and gravel have been recovered along the Susquehanna River, and locally gravel from glacial deposits has been used. Reserves of sand and gravel consist of sporadically distributed glacial deposits and flood plain deposits, few of which are large and homogeneous.

Clay and shale. South of Monroe and of New Albany the soft red Catskill shales are suitable for making brick. At other places, too, the softer Catskill shales would be suitable for brick making.

Glacial clay, which is common to many of the drift-filled valleys in the county, was once used to make common brick and tile. Where it occurs free of boulders, it may have considerable value to a local pottery, tile, or brick plant.

Coal. Coal of fair grade has been mined and marketed in Barclay and LeRoy Townships in the southwestern part of the county, also in Armania Township, along the western border. Reserves of workable coal are not large. Most of the coal which remains is dirty and bony, so that it is difficult to mine a clean product.

Gas. Four wells, ranging from 4,700 to 5,600 feet, were drilled to the Oriskany sandstone in the early 1930's to test gas possibilities in Towanda, Ulster, Wells, and Columbia Townships. All of them were dry. Other test holes in the county have also been dry. The presence of gas in Tioga County and the apparent absence of it in Bradford County would indicate the boundary of gas-bearing rocks as being between them. However, the similarity in structure and the lithology of the Oriskany sandstone and other rocks in the two counties prevents any such statement. Until otherwise proved, the eastward extension of the Tioga fields must be assumed a possibility.

REFERENCES:

Fettke, C. R., Subsurface Devonian and Silurian sections across northern Pennsylvania and southern New York: Geol. Soc. Am. vol. 44, 601-660, 1933.

BUCKS COUNTY

Area 617 square miles. Population 107,715

Bucks County lies along Delaware River above Philadelphia. Bristol is the oldest and largest borough. Doylestown is the county seat. The county has 758 miles of improved State highways, and is served by the Pennsylvania and the Reading railroads.

The rocks include granite gneiss, Hardyston quartzite, and Conococheague limestone in Durham Township at the north end of the county; the Wissahickon schist formation, gneisses, gabbro, and Hardyston quartzite at the south end; and all between is Triassic sediments and diabase except the small area of older rocks in and near Buckingham Mountain.

The mineral resources are limestone, sandstone, trap rock, sand and gravel, molding sand, iron ore.

Limestone. Bucks County is poorly supplied with limestone, although it occurs in three distinct areas. Pre-Cambrian limestone has a very limited exposure in Southampton Township. The old Vanartsdalen quarry, known to mineral collectors, is in this limestone. Cambro-Ordovician limestones occupy the valley of Durham Creek west of Riegelsville, and Buckingham Valley from Furlong northeastward to the Delaware.

Quarries were opened in these areas at an early day to supply stone for flux, agricultural lime, and building stone. Limestone was quarried and made into hydraulic cement 2 miles north of New Hope, about 1829-1833, for building locks, culverts, aqueducts, etc., on the Delaware Canal. Operations in recent years have been the production of crushed stone, principally for building roads.

The limestone in the many quarries in these areas is high in magnesia and fairly high in silica.

Sandstone. Micaceous quartzite, sericitic quartz schist, Triassic brownstone and sandstones of other colors, all of local origin, were used for building in the 18th century. There are sandstone quarries near Lumberville, Newton, Perkasie, Rushland, and Sellersville. In the 20th century black hornfels has been used in blocks for the walls of a few buildings. The principal use in recent years, however, is as crushed stone. This baked Triassic shale is quarried near Green Lane, Telford, and Point Pleasant, and quartzite in Buckingham Mountain.

Trap rock. Great irregular areas, many square miles, of diabase or trap rock are at the surface from Haycock Mountain southwest to the Montgomery County line and encircling Quakertown and Trumbauersville. Small areas extend southwest from Point Pleasant, and make a loop in the hills east of Kintnersville.

The principal use of trap rock is as crushed stone for concrete aggregate, road metal, and railroad ballast, and the largest quarry is at Rock Hill, 2 miles north of Perkasie. It is capable of producing about 3,000 tons daily.

Trap rock has been quarried at several places north of Quakertown and used for building stone. In a hill in Springfield Township 2 miles east of Coopersburg several quarries have been opened for "black granite," which is polished for monuments.

Sand and gravel. Huge quantities of sand and gravel for construction purposes are dug by floating dredges in the flood plain of Delaware River between Morristown and Tullytown. Bank sand and gravel is dug at Riegelsville.

Several grades of bonded molding sand are dug near Tullytown, an industry now many years old.

Brick shale. The softer shales, especially in the Brunswick formation, make excellent brick and they could be used for brick or tile manufacture in many parts of the county. These shales are used at a brickyard in Perkasie. Stockton shales are used by a brickyard at Southampton, and by a pottery at Doylestown. Red-burning residual clays from limestone in Buckingham Valley could be used for brick and pottery.

Paint ore. Umber was once mined on a small scale along the fault contact at the southeast base of Buckingham Mountain, where the road crosses the middle of the mountain.

Iron ore. The only openings known to have been made for magnetite were the Mine Hill, Rattlesnake, and Boyer or Kohl mines in Durham Township, and the Nicholas prospect over the line in Springfield Township. Mine Hill and Rattlesnake were the only ones of note and constituted the well-known Durham mine, but the product was mainly hematite.

The metallic content of a sample of 2,000 tons on the mine dump from Rattlesnake Hill was 48.65 percent iron, and the mineral components were about 18 percent quartz, 35.5 percent magnetite, 31.5 percent hematite, 6 percent feldspar, etc.

An analysis of a sample of 4,000 tons of ore at Mine Hill indicated the presence of 30 percent quartz, 43 percent hematite, 18 percent magnetite, and 7 percent limonite. Red ore from underground workings at Mine Hill carried about 29 percent quartz, 65 percent hematite, and 4 percent magnetite.

The Orchard mine on the north side of Rattlesnake Hill furnished limonite to the Durham furnace.

All the ore obtained from the Durham mines was comparatively lean but was low in phosphorus and sulphur. When operation of the Durham mines ceased in 1906 abundant ore was still available, but the cost of mining was too high for profit.

The Durham mine was first opened in 1698, and it furnished ore in 1727 to a furnace at Durham village.

Lead ore. About 200 tons of lead ore are said to have been taken from lodes mined at New Galena prior to 1870. Unusually fine specimens of galena and sphalerite have come from the New Galena mines. There is no evidence of reserves. Prospecting for ore in commercial quantity would be a poor venture.

BUTLER COUNTY

Area 794 square miles. Population 87,590.

Butler County lies north of Allegheny County and the Pittsburgh industrial district. It is in the Lower Allegheny Coal Area. Its mineral resources are coal, clay, shale, sandstone and glass sand, limestone, oil and gas, sand and gravel; there are large secondary industries in oil refining, cement, glass, lime, various clay products, and iron and steel.

Topography. This is a typical plateau county with broad hilltops steeply sloping down 200 to 400 feet to fairly wide, open valleys. As an exception, Lower Slippery Rock Creek has cut a recent gorge through an old stream divide in the northeast corner of the county. The lower courses of streams flowing into the Allegheny River have cut deep and narrow valleys because the Allegheny channel was lowered 250 to 300 feet when its direction of flow was changed during the last glacial period.

Rocks. The rocks of Butler County range from the middle of the Conemaugh down to the Pottsville. The Ames limestone in the middle of the Conemaugh caps many of the hilltops in the southwestern part of the county, and the lower Conemaugh rocks cover the hilltops throughout the southern two-thirds of the county. Allegheny rocks crop out in most of the valleys and completely underlie the northern third of the county. Pottsville rocks crop out in the valley of Slippery Rock Creek and its tributaries. Nearly all of the workable coals and clays occur in the Allegheny group.

Mineral resources. The Upper Freeport coal underlies a small part of Middlesex Township. The average thickness is about 42 inches, and it ranges up to nearly 6 feet. This bed has been extensively mined. The few mines on the Lower Freeport coal bed show coal between 40 and 50 inches thick. This coal is variable, ranging in thickness from 1 to 4½ feet. The Upper Kittanning coal has been mined locally on a commercial scale. The average thickness, however, is only about 27 inches. The Middle Kittanning coal seems to be more persistent than the others. Sections show from 2 feet to 3 feet 6 inches, with an average of about 30 inches. Most of the coal has a parting one to two inches thick in the upper half of the bed. The Lower Kittanning coal, locally absent, is being mined at several places where it is 30 to 36 inches thick. Locally the Brookville coal is 3 to 5 feet thick and averages 3½ feet. The Brush Creek coal, about 80 feet above the Upper Freeport, is from 3 to 5 feet thick in some of the townships in the southern part of the county.

Clay and shale are used for brick, sewer pipe, fire clay, cement, and pottery. Because of the unexposed position of the clays of the county, they are not well known. The Lower Kittanning clay is probably well-developed in this county as in adjoining counties. Mining would have to be by shaft or slope. Most of the clays range from 2 to 3 feet thick and are not of much value. Measurements and tests on the Lower Kittanning clay are not available. It is believed, however, that drill prospecting for clay and shale would prove large reserves of good quality and thickness.

Sandstone suitable for large structural work is abundant in the county. It has been used in the court house and several of the churches in Butler. None has been suitable for glass sand. Sand has been produced by crushing sandstone and by quarrying in the glaciated area.

The Vanport limestone has been extensively mined in the northern part of the county where it reaches a thickness of 22 feet. It may underlie a large part of the county and be available by shafting wherever it is needed. The Upper Freeport limestone is 5 feet thick locally and may constitute large reserves.

About 75,000 acres, or 117 square miles, of the county have been mapped as oil-bearing and it has been estimated that there are 180 million barrels of oil physically recoverable by present known methods. This includes, however, the recovery of all possible oil by repressuring the oil sands. This would make Butler County the third county in the State in oil reserves. Oil production in recent years has been about 450,000 barrels a year. At the present rate, therefore, the available reserves would last almost one hundred years. Gas production has not been large for many years. In 1920 it mounted to about 6 billion cubic feet, but by 1932 had decreased to 1⅓ billion cubic feet.

CAMBRIA COUNTY

Area 695 square miles. Population 213,459.

Cambria County lies just southwest of the center of the State. It is entirely within the Allegheny Mountains Area. The eastern boundary follows Allegheny Mountain and part of the western boundary follows Laurel Hill. The main line of the Pennsylvania Railroad crosses the county from east to west with branches up main valleys to the mines and other industries. Great steel works at Johnstown have added to the wealth of the county. The reserves of coal are large and mining has been active in the county for many years. Coal is the only mineral resource of outstanding value, though clays are worked and iron ore has been mined.

Topography. The relief is high, ranging from about 1,100 feet where Conemaugh River leaves the county to nearly 2,900 feet on top of Allegheny Mountain in the southeastern corner of the county. Broad areas through the center of the county are above 2,000 feet. Around Johnstown the hilltops are about 1,800 feet and the river is in a narrow valley at about 1,150 feet. Most of the streams have cut gorge-like valleys. The topography is distinctly of the plateau type with broad uplands and narrow steep-sided valleys.

Rocks. Aside from a few acres of Pittsburgh coal and rocks of the Monongahela group in two of the synclines, most of the surface rocks belong to the Conemaugh group and consist of shales, sandstones, thin limestones, and thin coal beds. The Allegheny group crops out along the west flank of Allegheny Mountain, the east flank of Laurel Hill, and in the valleys, especially where "brought up" by anticlines. The Allegheny group includes practically all the workable coal in the county, with four principal beds. The Upper Freeport (E) or "Lemon," the Lower Freeport (D) or "Limestone" bed, the Upper Kittanning (C') or "Cement" bed, and the Lower Kittanning (B) or "Miller" bed. Limestones occur under the Lower Freeport and Upper Kittanning coals. Clays underlie all the coals. The Pottsville group crops out along Allegheny Mountain and Laurel Hill. It includes several coals, massive sandstones, clay, and shale. The Mauch Chunk red shale and sandstone are 160 feet thick. The Loyalhanna limestone, 45 feet thick, is exposed in cuts across the anticlines. The Pocono group is 1,100 feet thick. Below the Pocono 400 feet of red Catskill beds are exposed in the arch of Laurel Hill anticline.

Mineral resources. Coal is the outstanding mineral resource. Original reserves are estimated at nearly 6 billion tons. For many years coal production has been large. It is estimated that 865 million tons have been mined out or lost, leaving an estimated 175 million tons of recoverable coal more than 3 feet thick, 1,400 million tons between 2 and 3 feet thick, and 1,390 million tons under 2 feet thick to be recovered in the distant future. The largest body of coal is thought to be in the B or Miller bed which ranges from 2½ to 6 feet thick, though the bulk of it is under 4 feet thick. The Clarion and "Brookville" beds are thought to be mineable in only a few of the townships, mostly along the eastern edge of the county.

Clays have been mined and used for making building brick and fire brick. These are in part plastic, in part flint. Of these the Lower Kittanning clay is from 3 to 12 feet thick and extensively mined and used for fire brick. Clays are present under the other coals, but have not been worked, probably because of the superior quality and quantity of the B clay and the Mercer clay. The most important of the flint clays is at the Mercer horizon. It has been worked near South Fork. Flint clays occur both above and below the Upper Freeport coal, the lower being the Bolivar clay. Shale at several horizons is suitable for making face brick and hollow tile.

Limestones occur in the Conemaugh and Allegheny groups. Only one of these, "the cement rock" under the C′ coal, appears to have been mined. It is dolomitic in character and was used for making natural cement. As the limestone is only about 6 feet thick and usually in three distinct benches, it cannot be counted as a resource of high value. The Loyalhanna limestone occurs in only two places. It is 45 feet thick and has been quarried for paving blocks and crushed for ballast.

The sandstones of the Conemaugh, Allegheny, and Pottsville groups are all suitable for rough structural work and have been extensively used. Some of these sandstones weather to a pleasing gray color, enhancing their value as building stones. Some of the Pottsville sandstone seems pure enough to be used as glass sand of fair quality.

One bed of iron ore, 50 feet below the Upper Freeport coal, and from 1 foot to 2 feet 3 inches thick is of interest mainly because it was originally mined near Johnstown for two small furnaces and is responsible for the location of the present huge Bethlehem Steel plant at that point. The ore after calcining was self-fluxing.

CAMERON COUNTY

Area 401 square miles. Population 6,852.

Cameron County, just northwest of the center of the State, lies half in the High Plateau Area and half in the Endless Mountains Area. It is distinctly mountainous land, only 11 percent of the county being in farms. Much of the county is in State forests and State game lands. The county thrived when its primeval timber was lumbered off. In time second growth timber will reach maturity and become a permanent asset, supporting permanent wood-working industries. Meanwhile, it continues to be the hunters and fisherman's paradise. The Pennsylvania Railroad follows the main drainage lines through the county. Its mineral resources are minor, some coal in the hilltops, sandstones, shales, and a show of gas.

Topography. Most of the county is a high upland, 2,000 to 2,300 feet above sea level, with steep-sided ravines, 800 to 1,100 feet deep. Locally the streams are so close that the intermediate divides are narrow and saw-toothed. In general, the inter-stream divides are fairly constant in elevation, locally widening; here they are farmed. The Sinnemahoning at Benezette is 1,000 feet above sea level, the West Branch at Beechwood 1,250 feet above sea level. Only the western part of the county had been topographically mapped in 1943.

Rocks. The rocks of Cameron County lie in a series of northeast-southwest anticlines: the Chestnut Ridge anticline in the southeast corner, the Wellsboro through Driftwood, the Marshlands through Sterling Run, the Sabinville through Emporium, and the Harrison anticline in the northwest corner. Between these anticlines the hilltops contain small basins of Coal Measures, 125 feet of Pottsville rocks, 50 feet of Mauch Chunk, 470 to 745 feet of Pocono, 350 to 500 feet of Catskill, and more than 350 feet of Chemung rocks. The Pocono and underlying strata form the walls and bottoms of the valleys and canyons.

Mineral resources. No detailed mapping or study has been made of the rocks or mineral resources of this county. The Lower Kittanning or Dagus bed, averaging 3 feet thick, underlies an estimated 2 square miles; the Clarion (Clermont), 2 to 4 feet thick, 7 square miles; and the Alton or Mercer coal, 12 square miles. Mining has always been on a relatively small scale. It has been estimated that the county has 20 million tons of recoverable coal more than 2 feet thick and 25 million tons of recoverable coal under 2 feet thick. No oil has yet been found in the county. One small gas field has been found, in the northwest corner of Shippen Township. Cameron County lies east of the principal gas belt. There is no known reason why other gas pools may not be found, but, as in all the marginal areas, only sporadic occurrence may be expected. The clay and shale beds associated with the coal beds have been mined on a small scale. No thick beds have been noted, but such observations as have been made show both soft and flint clays. They occur at the top of high hills, usually some distance away from the streams and railroads. Some of the sandstones should be suitable for masonry and some stone may be suited for general building purposes.

CARBON COUNTY

Area 405 square miles. Population 61,735

Carbon County is in eastern Pennsylvania between Monroe and Schuylkill Counties. The eastern half of the county is on the Pocono Plateau and the rest of the county in the anthracite area. The northern half of the county is sparsely settled, forested upland; the southern third is devoted to farming and manufacturing. The eastern ends of the Southern and Eastern Middle Anthracite fields cover about 10 square miles along the western edge of the county. Lehigh River is part of the northern boundary, then cuts across the county through Mauch Chunk and out through Lehigh Gap in Kittatinny Mountain, which forms the south border.

Lansford, Lehighton, Palmerton, and Summit Hill boroughs have more than 5,000 population. From Lehigh River west, railroads and highways are numerous; east of the river in Penn Forest and Kidder Townships improved roads are few and far apart.

The entire county has been glaciated but only the very northern part was covered by ice during the last glacial period. The only extensive deposits of drift, except in parts of Kidder and Lehigh Townships, are in the valley of Aquashicola Creek.

Rocks. The rock formations exposed range in age from the Coal Measures down to the base of the Tuscarora sandstone, of early Silurian age, in all about 19,000 feet of strata. The Tuscarora crops out along Kittatinny Mountain, and the youngest rocks are exposed in the Panther Creek coal basin near Ashton, and in the Beaver Meadow syncline near the Luzerne County line.

The geologic structure of the county is major folding complicated by faulting. Anticlines and synclines trend northeast. Broad Mountain is an anticlinal ridge of the Pocono sandstone, and Kittatinny Mountain is a steep monoclinal ridge with northwest dip. The northeastern part of the county is capped by nearly horizontal Catskill sandstone.

MINERAL RESOURCES

Anthracite. Though occupying only about 10 square miles in the county, it is estimated that there were originally 500 million net tons of anthracite in the eastern end of the Southern field and about 120 million tons in the eastern end of the Eastern Middle field, or 620 million tons together. Of this it is estimated that 344 million tons are left of which 189 million tons are recoverable at present rates of recovery. The coal of this county is of very high rank, having only about 2 percent volatile matter and a specific gravity of 1.65. River coal is dredged from the Lehigh and may continue to be after each high water for years to come.

Paint ore. A low-grade iron ore used for making paint occurs between Marcellus shale and Oriskany sandstone. It crops out from one mile west of Germans eastward to Little Gap. The best ore seems to be east of Lehigh River and most mining has been near Hazard and Aquashicola.

This ore resembles impure blue limestone devoid of bedding but with higher specific gravity, because it is about 34 percent iron. The original ore is siderite, iron carbonate, in a bed that averages somewhat less than two feet thick. In most places the ore bed stands at a high angle; the continuity is interrupted by faults and synclines in which the angle of dip is low.

Mining of paint ore began here in 1856. Supposing 200,000 tons have been taken, the reserves may still support the industry for many years.

Limestone. The limestones of Carbon County are of little importance. Both the Helderberg and Onondaga limestones cross the county in narrow bands in the valleys of Aquashicola and Lizard Creeks. They rarely crop out because of the cover of glacial debris and hillside talus. Both were once quarried north of Palmerton, and hydraulic cement was made. It is said all the masonry of the Lehigh canal, built in 1824, was laid with it. No use has been made of this limestone in recent years, perhaps because of chemical or physical difficiencies, as the Onondaga limestone is argillaceous and the Helderberg is slaty.

Sandstone. Gray, red, and greenish sandstone suitable for use as building stone and in rubble walls is abundant. Where the Pocono sandstone is at the surface, walls are gray, and where the Mauch Chunk formation crops out, walls are red. Float stone is so abundant that few quarries have been opened. Tough red sandstone in the Mauch Chunk series has been quarried near Lehigh Tannery. The principal products were curbstone, paving blocks, and crushed stone. Building stone could be produced, of course, on demand. Many other quarry sites are advantageously situated as regards transportation.

Slate. Roofing slate has been quarried successfully at only one place in Carbon County, and operations were discontinued there in 1915. The location is in a small valley just north of Aquashicola. Four quarries, full of water, are in the Hamilton-Marcellus group of Devonian age. Although it is possible that usable slate occurs elsewhere in the county, this location is proved; and although there is no promise of a renewal of quarrying, this slate belt merits some consideration as a reserve.

Shale. Soft red shales in the Mount Pleasant division of the Catskill beds might be used for making brick but they occur on the Pocono Plateau less handy to fuel and market than the softer beds of the Mauch Chunk red shales that occur in lowlands west of Mauch Chunk and north of Broad Mountain and are suitable. There are no brickyards in the county.

Sand. Strongly bonded molding sand used for heavy pipe and machinery castings has been dug on the river flat at Lehighton since 1914. Similar deposits might be looked for farther down the river.

Building sand is made at Palmerton by crushing a high-silica sandstone that crops out high above the river. As the Oriskany and Palmerton sandstones crop out in Stony Ridge all the way across the south end of the county, opportunity is offered for further development of silica sand. Sand and gravel can be derived from glacial deposits, particularly in the northern part of the county.

CENTRE COUNTY

Area 1,115 square miles. Population 52,608

Centre County is the second largest in Pennsylvania, and, as its name implies, is located in the geographic center of the State. Bellefonte, the county seat, with 5,304 inhabitants and State College with 6,226 are the largest boroughs. The Pennsylvania State College, founded here in 1855, had more than 6,000 full-time students in 1940.

One of the first important industries in the county was the mining and smelting of iron ore, but these operations have long been abandoned. The chief mineral resources being developed at the present are coal, clay, limestone, and sandstone. Railroad transportation is furnished by the Pennsylvania, the New York Central, and the Bellfonte Central. Four main highways traverse the county, and hard-surface roads are available to nearly all parts.

Rocks. The rocks of Centre County range from limestones of Upper Cambrian age to lower members of the Conemaugh group of Carboniferous age. With exception of the Allegheny Plateau at the west, which contains rocks of Carboniferous age, the county is traversed diagonally by wide limestone valleys, interrupted by narrow-crested sandstone ridges. The oldest formations, the Cambrian and Ordovician limestones and dolomites, crop out in the large fertile valleys that characterize the eastern part of the county. The Silurian rocks form the slopes and crests of the high ridges east of Bald Eagle Valley. The Devonian rocks occur as a long straight band in Bald Eagle Valley and on the east slope of the Allegheny Front. Pocono rocks of Mississippian age underlie the crest of Allegheny Mountain, which has a greatest altitude of 2,580 feet.

Mineral resources. Coal. Coal is confined to the part of the county northwest of Allegheny Mountain. Except in Burnside Township the Coal Measures rise strongly toward Allegheny Mountain. A very few small hilltops are capped with the Upper Freeport coal. Today all mining is on the Lower Kittanning or older coals, and these are approaching exhaustion. The coal left is mainly in thinner beds, such as the Middle Kittanning or coals in Burnside Township, of which our knowledge is very meager. The Lower Kittanning and "Brookville" beds generally have less than 4 feet of coal. Because of the shallow depth of most of the coal, considerable strip mining has been done. The county is estimated to have considerable coal left, but mostly low-grade or in thin beds.

Clay and shale. The county contains several types of clay. On the plateau, soft plastic and hard flint clays occur, in particular under the Mercer, "Brookville," Clarion, and Lower Kittanning coals. Flint clay occurs at each of these horizons but notably at the Mercer horizon. It has been extensively mined at and near Sandy Ridge, at Buck Creek, near Peale, Monument, Snow Shoe, and Orviston. These deposits are much reduced or exhausted. Doubtless, prospecting will reveal many deposits not known now. The clays under the "Brookville," Clarion, and Lower Kittanning coals are commonly soft, but occasionally some flint clay accompanies them.

In Nittany Valley clay resulting from the weathering of the limestones covers much of the surface from a few to more than 100 feet deep. White clay resulting from the decomposition of the Gatesburg sandstone has been mined near Scotia and Furnace Road. This highly siliceous clay has been used for furnace cement and saggers and may be suitable for white ware or paper if the silica is removed. Some of the Devonian and other shales are suitable for brick and tile and have been used on a small scale.

Limestone. Centre County contains an abundance of limestones suitable for various uses, and is one of the leading producers in the State. More important is the fact that it has what probably is the best grade of limestone in the State, namely, the Bellefonte ledge in the Lowville member. It averages almost 98 percent calcium carbonate, 1 percent magnesium carbonate. It is 77 feet thick and best developed in the vicinity of Bellefonte and Pleasant Gap, where it is mined extensively. The products are quick lime, hydrated lime, ground and pulverized limestone, fluxing stone, and crushed stone. Limestone is used in large quantity for building stone.

Sandstone. The Pottsville and Pocono sandstones underlie Allegheny Mountain and could be used for building stone, as is the Medina or Tuscarora sandstone that forms Tussey, Brush, Nittany, and Bald Eagle Mountains. This latter is stripped from Bald Eagle Mountain near Port Matilda for making refractory brick. Sand from the weathering of the Gatesburg formation and the Oriskany sandstone is used for building sand.

Iron ores. Iron ores are associated with the coal beds in the western part of the county, but are thin and irregular. A carbonate ore not exceeding 4 feet thick is present in the Mauch Chunk formation in Burnside Township. The Chemung formation contains iron ore at some places. Brown hematite occurs as a replacement mineral in cavernous limestone along Sinking Creek in Potter Township and in the southern part of the county near Pennsylvania Furnace. What possibly may be a present source of supply is the brown hematite lump and wash ore in the Gatesburg dolomite at Scotia. Under stimulus of the demand of World War II, these deposits were prospected under supervision of U. S. Bureau of Mines. Preparation for mining under federal auspices was advancing in 1944.

CHESTER COUNTY

Area 760 square miles. Population 135,626

Chester County is west of Delaware and Philadelphia Counties and mostly in the Piedmont Highland. In general it is an area of low, rolling topography. Coatesville, West Chester, and Phoenixville are its largest municipalities. Beside railroads and U. S. Routes 1, 30, and 322 it has 969 miles of improved State highways.

Rocks. A narrow transverse valley, known as the Chester Valley, underlain by Cambro-Ordovician limestone separates the northern and southern parts of the county, both of which are underlain by igneous and metamorphic rocks with complex structural relations. Along the north and northeastern border there is a zone of Triassic shales and sandstones. Near Elverson, Warwick, and St. Peters these are intruded by diabase. The other rocks in the northern half of the county are mainly gabbro and gneiss. Welsh Mountain is underlain chiefly by the Chickies quartzite. In the southern half, the rocks are chiefly schist, gneiss, and gabbro, with patches of serpentine and marble.

From the rocks of Chester County have come the ores of iron, copper, lead, and zinc, and a host of non-metallic mineral resources which have made it one of the most interesting mineral producers in the State. These individual mineral resources and their possible reserves are considered below.

METALLIC ORES

Iron. Magnetite was mined at the French Creek mines from early in the 19th century until 1928, at which time all operations ceased with the exhaustion of ore. The ore occurred as a replacement of limestone lenses in gneiss adjacent to diabase intrusions. It is of the Cornwall type of magnetite deposit and has been described in detail by Smith.[1]

Hematite was once mined near Doe Run village, but the amount must have been small, and it is unlikely that there are any minable reserves of ore nearby.

Chromium. In the southwest corner of the county chromite was mined prior to 1890 at several places in the serpentine rocks. Probably considerable ore was taken from the Scott and Philips mines, which worked at the same time as the famous Wood mine in Lancaster County. Much disseminated chromite may remain as an unmined low-grade ore body adjacent to the old workings. The character of the ore and its usual occurrence as lenses and pockets in the serpentine belt indicate the possibility of other such deposits being found. The surface of most of this area has been fairly well explored, however, and it is doubtful that any other deposits will be discovered without the aid of improved geophysical methods.

Placer chrome, or chrome sand, occurs in the streams that traverse the serpentine belt. During World War I, a mill was built on Black Run two miles west of Nottingham to recover this sand. Although profitable operation may be doubtful, much of this chrome could be recovered from the streams.

Copper. Chalcopyrite was mined, and some copper produced, incidental to the mining of lead and zinc at Phoenixville. Some of the chalcopyrite was goldbearing. Neither copper nor gold was obtained in quantities sufficient to warrant any interest in further mining for these metals.

Magnesium. During several short periods between 1835 and 1871 magnesite was produced from mines in the serpentine belt five miles southwest of Oxford. In 1921 an unsuccessful attempt was made to develop the old workings just east of Goat Hill, a few rods north of the State line. This work showed that the network of magnesite veins was too small to warrant further development. The presence of magnesite in commercial quantity is, of course, possible even though the old operations were not successful in finding much. Detailed exploration, involving considerable expense and with no assurance of success, would be essential to finding it, and under existing conditions this would hardly be merited.

Lead and Zinc. Ores of lead and zinc were mined near Phoenixville from 1809 to 1826, 1851 to about 1870, and in a minor way from 1918 to 1920. For the most part, the mines were in the granite and gneiss area about two miles south of Phoenixville. Several mines, notably the Perkiomen, however, were located four miles east of Phoenixville in the Stockton shales of Triassic age.

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[1] Smith, L. L., Magnetite deposits of French Creek, Pennsylvania: Pa. Topog. and Geol. Survey Bull. M 14, 1931.

The ore minerals were chiefly galena, pyromorphite, sphalerite, and chalcopyrite (if copper was mined). The mineralogy is complex, however, and many rare and common minerals were associated with the ore and gangue. The deposits are of hydrothermal origin, located in most instances in and along fissures and faulted zones or fault planes. Details of the ore, its occurrence, and the mining operations have been compiled by Miller.[1]

As Miller points out, the Phoenixville district may again be a producer of lead and zinc. However, any estimate of reserves is entirely dependent upon carefully planned and executed exploration work in the vicinity of the old mines and in the direction of any possible extension of the ore bodies.

NONMETALLIC RESOURCES

Graphite. The Pickering gneiss underlies an area one to four miles wide extending from near Phoenixville westward to Lyndell; it also underlies a smaller area just west of Pughtown. This gneiss is graphite-bearing. Disseminated graphite flakes, ranging from less than one to occasionally more than six percent of the gneiss are common in these two areas. The Pickering Creek area was first worked for graphite in the late 1870's. Sporadic operation characterized the area until about 1895. From then until about 1910 there was considerable activity. Fourteen mines produced graphite at one time or another; several mines yielded large tonnage. The graphite-bearing gneiss which the mines worked seldom contained less than an average of three to five percent graphite.

In 1942 and 1943 the area adjoining the property of the old Consolidated Graphite Company on the west, about one mile southwest of Chester Springs, was briefly prospected, a mill erected by Defense Plant Corporation, and flake graphite of several grades produced for a short time until November 1943.

Reserves in this area are very large. But the tenor of most of the "ore" is less than four percent. When higher grade and more easily mined graphite is available from Madagascar and Ceylon, this can no longer be considered an ore. It is reasonable to expect that detailed investigation of the entire district may outline individual areas where the tenor of the ore is high enough to warrant domestic production, especially with new and improved milling procedure. Such an investigation would take considerable time and necessarily entail much expense.

Pegmatite Minerals. From pegmatites that have intruded most of the rocks in the southern part of the county there has been considerable production in the past of feldspar, kaolin, quartz ("flint"), and some mica.

Potash feldspar was mined extensively in West Nottingham, London Grove, and New Garden Townships from before 1900 until about 1928. At one time the mines of this district supplied more high grade feldspar than any other in the United States. Details concerning the location of all the old mines, the occurrence and character of the ore, and its production are considered elsewhere.[1] Although many of the open pit mines exhausted the feldspar content, there may be small reserves of No. 2 spar at many of the old workings. More important, there may be large reserves of feldspar in pegmatite dikes that have not been discovered.

Kaolin was mined mainly near Hockessin and between Avondale and Toughkenamon. In all cases the kaolin is residual from the weathering of feldspar minerals in pegmatite dikes. There has been no production for many years. As with feldspar, undiscovered pegmatite zones may contain kaolin reserves.

Quartz, or "flint" as it is commonly called, was produced and sold as a by-product to the mining of both kaolin and feldspar. None of the quartz typically found in these pegmatites is of proper quality to be used in the manufacture of piezo-electric plates.

Commercial mica has been produced only in small quantities from the pegmatite belt of the county, and any production was incidental to the mining of feldspar and, to a lesser degree, kaolin. Most of the mica is of inferior grade, having many mineral inclusions, and being cloudy, wavy, and fractured. However, considerable mica that has been thrown on waste dumps could be used commercially. One mile south of Fairville there is abundant mica of good quality partially covering a large field. This may indicate an underlying pegmatite as the source.

Limestone and Dolomite. The Chester Valley is underlain by the Conestoga and Conococheague limestones and the Vintage dolomite. It extends from Atglen on the west to West Conshohocken on the east, and it is nowhere more than three miles wide. In the eastern half of the valley there are or have been seven large quarries that have produced fluxing stone, road metal, building stone, and stone for agricultural limestone and lime products. Some of the limestone is dolomite, and of good grade. Stone from the old

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[1] Miller, B. L., Lead and zinc ores of Pennsylvania: Penna. Topog. and Geol. Surv. Bull. M 5, pp. 21-46, 1924.

[1] Stone, R. W., and Hughes, H. H., Feldspar in Pennsylvania: Topog. and Geol. Survey Bull. M 13, 1931.

Dougherty quarry has been used for the extraction of magnesia. It is possible that a sufficient quantity of high grade dolomite is present to be of interest to producers of magnesium and magnesia products. Details of the Chester Valley limestones have been presented elsewhere.

Near Doe Run, Avondale, and Landenburg are three separate areas of Cockeysville marble. In the past this formation has been quarried for various purposes. Much of it made excellent fine white building stone. There are abundant reserves of the marble. Although it is seldom homogeneous and of consistent high quality, careful investigation by drilling would doubtless find other favorable quarry sites.

Sandstone and Quartzite. Triassic sandstones underlie part of the northern section of the county. These sandstones would be suitable for building purposes.

The Chickies quartzite bounds the Chester Valley on the north and makes the crest of Welsh Mountain. It has been quarried for crushed stone and building stone. There are abundant reserves.

The Setters quartzite underlies the area around London Grove and the south side of the ridge between Avondale and Toughkenamon. It has been quarried at all these places for building stone, flagstones, and sills. The quarried products dress well and are attractive.

Shale and Clay. Most of the Triassic rocks in the north and northeastern part of the county are shales. The Brunswick formation, consisting of both red and green shales, may at many places be used for brick manufacture. In 1940 there was one brick plant in the county. Located east of Phoenixville, it used red and blue shales of the Stockton formation.

Along the north flank of Welsh Mountain certain schistose phases of the Chickies quartzite, high in original feldspathic and micaceous minerals, have weathered to a white micaceous residual clay. This clay is mined near Narvon, in Lancaster County. It is reasonable to expect that sufficiently large bodies could be found in this county to warrant operations.

Clays residual from the limestones of the Chester Valley are suitable in most cases for the manufacture of brick. These clays are of variable thickness, capping the irregularly eroded surface of the limestones.

Building Stone. The use of the limestones, marbles, sandstones, and quartzites of the county as building stone has been mentioned. Beside these, diabase, gabbro, gneiss, schist, and serpentine have been more or less extensively quarried for building stone and crushed stone.

"Black granite" monumental stone has been quarried from a large mass of diabase at St. Peters for many years. Reserves are very large. South of West Chester there are many small areas of serpentine from which considerable building stone has been quarried. There are very large reserves.

Although there has been little or no quarrying of gabbro, gneiss, and schist in the county, there are tremendous reserves of these rocks, many of which would serve as attractive building stones, and some (especially the gabbro and gneiss) which would serve well as crushed stone for railroad ballast or road metal.

Corundum. In Newlin Township, 1½ miles northeast of Unionville, a small area of serpentine cut by several diabase dikes was once worked for corundum. Between 1839 and about 1882, several large masses of corundum were found weathered out of the rock; some were sent to England, and later the ore was ground in a mill set up on the property. From the evidence of the old small open pits and trenches from which the ore was removed, and numerous small prospect pits, the ore occurrence was sporadic and in small concentrations. Corundum is used as an abrasive. There it little, therefore, to justify a large expenditure of money in the hope of commercially producing corundum in the county.

Garnet. From several mines north of Chester, garnet was once produced from garnetiferous schist for abrasives. Production was small and it is doubtful whether these deposits could ever be profitably worked with the competition of cheap artificial abrasives.

CLARION COUNTY

Area 599 square miles. Population 38,410

Clarion County is in the north-central part of western Pennsylvania. It all lies in the Lower Allegheny Coal Area, with the Allegheny group covering the hilltops throughout and the Pottsville and Pocono rocks in the valleys. Coal, clay, limestone, sandstone, and oil and gas are its leading mineral resources. It is fairly well supplied with railroads.

Topography. This is a typical plateau county with the hilltops rising to a common level that ranges from 1,500 feet in the southwest corner to almost 1,700 feet in the northeast corner, and on the Kellersburg anticline on the east side of the county. The ridge tops are not wide except in the north end of the county, but some of them extend long distances at about the same level. In parts of the county the valleys have gentle, even slopes, in others, as near Clarion River and Redbank Creek, they are narrow and steep-sided. Valleys range from 200 to 500 feet deep.

Rocks. Small patches of the Conemaugh formation cap the hills in the southern third of the county; otherwise, except in the north end of the county, the hilltops throughout are capped with Allegheny rocks, which include the Freeport, Kittanning, and Clarion coals and clays, and the Vanport limestone. The Pottsville series includes the Homewood sandstone locally massive, but frequently represented only by shale, the Mercer group, and the Connoquenessing sandstones, usually present and locally fairly massive. The Pocono group appears to be represented by the lower part of the Burgoon sandstone, the Patton red shale at its base, and the Shenango and Cuyahoga sandstones and shales. At the north it is probable that all of the Burgoon sandstone has been eroded and that the Pottsville is underlain by the Patton red shale or even that may be removed. The lower sands and shales need to be studied further in the light of a changed interpretation of those beds elsewhere.

Mineral resources. The Upper Freeport coal is 3½ to 5 feet thick where its normal roof of shale is present. Over large areas the shale cover has been replaced with sandstone which lies on an old irregular erosion surface that is likely to cut out at least the upper part of the coal. The area of this coal is limited to the hilltops in the south part of the county. The Lower Freeport coal is also of limited extent. At the west it is likely to be thin, 1 or 2 feet, but at the east it thickens. The Upper Kittanning coal is commonly thin and irregular, ranging from a few inches to 7 feet. The Middle Kittanning coal is even less persistent than the Upper Kittanning and is generally thin or lacking. The Lower Kittanning coal underlies a large part of the county and is very persistent, about 3 feet thick. It thins to the northwest and is lacking locally.

The Clarion coals are thin to the east, but workable to the west. The "Brookville" (Mercer) coal is commonly thin or if thick (up to 15 feet) it is split up into unworkable benches. The "Craigsville" coal of earlier reports appears to be the same as the Lower Clarion or Pardoe coal. Estimates of coal reserves indicate 110 million tons over 3 feet thick, and 600 million tons of coal 2 to 3 feet thick, with perhaps 700 million tons recoverable from beds below 2 feet thick in the distant future.

Clarion County lies almost in the center of the oil and gas belt of western Pennsylvania. The county has long been a prolific producer of both oil and gas. Starting in 1866, the production of oil built up to 3,900,000 barrels in 1874, then declined to a recent production of less than 150,000 barrels. The Venango Third sand has been most prolific, but the Fourth, Hundred-foot, Thirty-foot, Bowlder, and Fifth sands have produced oil. Gas has come from the First, Big Injun, Tiona, Speechley, and Bradford sands. There are estimated to be 20 million barrels of oil obtainable by present methods, including repressuring of the sands, at present prices, but 180 million barrels all told, of which 75 million barrels are physically recoverable when and if the price becomes high enough. The production of gas in Clarion County reached 15 billion cubic feet in 1927, but has since declined.

Clays appear to be abundant in the county, though locally many of them are too high in iron for refractory purposes. The Lower Clarion clay is being mined for tile and fire brick and the Lower Kittanning clay, with which flint clay occurs, has been mined. The Mercer flint clay, 1 to 12 feet thick, has been mined extensively in the past, especially around Lucinda at the north, and it is still mined and used at Climax and St. Charles. The flint clay fuses at cone 33 to 34, but excessive iron has detracted from its use. The flint clay under the Lower Kittanning clay has been stripped in many places between Strattonville and Sligo, but it is high in iron. The Middle Kittanning clay and shale suitable for brick and tile are abundant.

The Vanport limestone is 6 to 8 feet thick in the eastern part of the county and 10 to 20 feet in the western part, but is lacking over rather wide areas. It has its usually high calcium carbonate quality. It is at present used mainly for road building and ag-lime. The Upper Freeport limestone is locally present and is used for ag-lime.

The Homewood and Connoquenessing sandstones are locally white and pure and have been used rather extensively for silica brick for iron and blast furnaces and for other purposes. The Kittanning sandstone has been used for building purposes, but weathers to a dull gray. This and the other sandstones are used for road building and massive masonry. Rock for dimension stone is not abundant.

Iron ore 6 to 14 inches thick, but locally up to 6 feet thick, is coextensive with the Vanport limestone and has been extensively stripped along its outcrop. Nodular ore is present in many of the shales, especially below the Lower Kittanning coal in the northwestern part of the county, and iron ore in an almost continuous bed is found about 10 feet below the Mercer ("Brookville") coal.

CLEARFIELD COUNTY

Area 1,144 square miles. Population 92,044

Clearfield County lies just west of the center of the State and is almost entirely in the Allegheny Mountains Area. The northwest corner is in the Lower Allegheny Coal Area. The first coal was shipped from the county in 1804. The county's position on the eastern edge of the coal field and the high quality of its coal beds led to their extensive development at an early date. Railroads built to bring out timber later served to carry coal. In addition to the coal, the county has long yielded large quantities of high-grade fire clay. The production of coal is on the decline, owing to the approaching exhaustion of the thicker, high-grade deposits. There are still large quantities of thinner high-grade coal, and fair reserves of high-grade clay.

Topography. Clearfield County is on a mature, dissected plateau. The uplands range from 1,400 to 2,300 feet, where major anticlines cross the county. The Atlantic-Gulf divide crosses the northwestern corner of the county. For the most part streams have cut steep-sided valleys, and locally the relief is very great.

Rocks. The rocks are almost exclusively Lower Pennsylvanian. The underlying Mississippian rocks crop out in the valleys of the northeastern part of the county and locally elsewhere.

The Conemaugh rocks cap the hills throughout the southern and western part of the county and in the DuBois area. Its coals are thin and are not mined commercially. Its sandstones have value for local construction and its shales have been used for making brick and tile.

The Allegheny rocks contain four valuable and widely worked coal beds, the Upper Freeport limestone, the Freeport sandstone, and fire clays and shales. The Pottsville rocks include coal beds, two massive sandstones, and valuable fire clays.

Mineral resources. Coal. Along the southeast edge of the county, the Lower Freeport (D) or Moshannon coal occurred in a long basin. It was 4½ to 6 feet thick and of high quality. In the 1870's this coal established a high reputation as "Clearfied coal," and by 1900 most of it had been mined out. In the same basin, however, the Upper Freeport (E), Middle Kittanning (C), Lower Kittanning (B), and "Brookville" (A) coals are all mineable. The E and C are thin, the others thick, so that mining has continued and there is still much unmined coal. In other parts of the county the coals have proved less dependable; locally they are 5 feet thick, but more commonly they are less than 3 feet thick. Considerable mining is being done on coal 2 feet thick. The high quality of the coal has contributed materially to such mining. The original reserves are estimated to have been 4,390,000,000 tons. By 1944 about 435,000,000 tons have been removed or lost. There are still 175,000,000 tons in beds more than 3 feet thick, 1,000,000,000 tons in beds 2 to 3 feet thick, and in the future 1,390,000,000 tons may be obtained from beds less than 2 feet thick. Crop coal and pillar coal have been extensively recovered either by stripping or underground digging. Such secondary recovery has been in progress for more than 40 years.

Oil and gas. There is thought to be no oil in the county and, so far, commercial gas wells have been confined to the northwestern corner. There is no known reason why some gas should not be produced from domes along Chestnut Ridge, which crosses the north-central part of the county. Other parts of the county have not been thoroughly tested, but large quantities of gas are not to be expected.

Clay. Clay and shale have long been an important mineral resource in this county. Workable beds of clay occur chiefly in the Mercer, A, A′, and B horizons. Clays under the younger coals are doubtless workable locally. The most valuable clay is at the Mercer horizon. In two areas, the Morgan Run district in the southeast center of the county, and the Anderson Creek area, northwest of Curwensville, the clay at this horizon contains nodules of diaspore. The alumina content of these clays is high, locally being 70 percent. These clays have been used in making special high-refractory brick and high-temperature cements. Much of the clay in these areas has too much iron to be suitable for refractory purposes and a study is being made as to the possibility of using such clay for the production of aluminum. Much of the Mercer clay is flint clay. Some valuable clay also occurs at the C and E coal horizons. Locally these clays are 18 feet thick.

Sandstone. Near Curwensville the Homewood sandstone is very massive and has been extensively quarried, especially for bridges. The Clarion sandstone has been mined in the western part of the county and seems to be equally suitable for structural work. Near McGees Mills some of the sandstone has been ground for sand. Near Madera, the upper part of the Connoquenessing has been used for curbing.

Limestone. Limestones, though present in the county, are not prominent and none have been quarried commercially. Local use is for ag-lime.

Bog ore. Bog ore occurs on the small flood plains and on small terraces above many streams in the county. Several deposits of high-grade bog ore for use in the pigment or gas purification industries have been found recently along Moravian Run in Graham and Morris townships. Present knowledge indicates many undiscovered deposits ranging in size up to 4,000 tons.

CLINTON COUNTY

Area 902 square miles. Population 34,557

Clinton County, just north of the center of the State, lies mostly in the Endless Mountains Area, but the south third is in the Ridge and Valley Area. The West Branch of the Susquehanna River flows through a picturesque valley in the center of the county. The southern third of the county is well served by roads and railroads. The rest of the county has roads in some of the valleys and on a few of the ridges. The mineral resources are limestone, clay, coal, sandstone, and ganister rock.

Topography. The north half of the county has not been mapped (1943). The topography is typical plateau uplands, dissected by streams which have cut deep, narrow valleys. The relief is 1,500 feet in many areas of the county. On the broad uplands, the minor drainage may be in broad, open valleys from 100 to 500 feet deep. In the south end of the county mountains reflect the resistance of different rock types to weathering. The valley at Lock Haven is 550 feet above sea level. Bald Eagle Mountain is 1,700 to 2,000 feet high and the top of Big Mountain reaches almost 2,300 feet.

Rocks. The rocks of this county range from the Cambro-Ordovician limestones up to the Allegheny group in the Coal Measures. The section will not differ greatly from that given under the Ridge and Valley description. From Allegheny Mountain northward, the uplands are of Pennsylvanian rocks and the valleys in Mississippian rocks, except where anticlines have brought up the underlying Devonian. The Lock Haven-Williamsport valley is underlain by the Middle Silurian and the Lower and Upper Devonian. The Catskill of the Upper Devonian underlies the hilly zone between the valley just mentioned and Allegheny Mountain. South of the Susquehanna River and Bald Eagle Creek, the mountains are underlain by Silurian rocks and the intervening valleys by Ordovician rocks.

Mineral resources. Mining is a very minor industry in this county at the present time. Clay is the chief product; some coal mining, a small amount of sandstone and limestone quarrying, and some sand and gravel digging constitute the other exploited mineral resources.

Coal. Ten million tons of coal are estimated to be in beds more than 3 feet thick, 20 million in beds 2 to 3 feet thick, and 40 million tons recoverable in beds less than 2 feet thick. Detailed surveys may reveal more coal than this. The coal is on the plateau tops and far from the present railroads.

Oil and gas. There is probably no oil and little commercial gas. A small gas pool with a reported show of oil was found on Kettle Creek some years ago and there may be other pools. Past experience is not encouraging for future production.

Clay. Plastic and flint clays in Clinton County have been extensively mined, chiefly for refractory purposes. Some of the clays are too high in iron for this purpose and most of the mining has ceased. The county has been fairly well prospected. Moderate reserves of good quality plastic and flint clay remain.

South of Allegheny Mountain the Silurian and Upper Ordovician shales should have unlimited supplies for brick and tile. The calcareous black Trenton limestone or shale has been used for making paint and for a filler. Some of the Devonian shale may also prove of value.

Limestone. Limestone has been found in abundance in the south end of the county. The Onondaga, Helderberg, Keyser, and Tonolaway limestones, several hundred feet thick, cross the county and have been used on a small scale for road building and ag-lime. The Tully, 90 to 240 feet thick, has been quarried between Lock Haven and Mill Hall. The Cambro-Ordovician limestones floor the Nittany, Nippenose, and Sugar Valleys completely. Unfortunately, no railroads enter these valleys and Sugar Valley is some distance from the nearest railroad. As a result these limestones have not been adequately tested. No doubt they are similar to those around Bellefonte and with transportation facilities might readily support similar industries.

Sandstone. Sandstones are abundant in the valleys throughout the north part of the county, and Bald Eagle and other mountains of the south part contain fine-grained sandstone and quartzite suitable for silica fire brick and for building stone. By careful choosing, stone suitable for buildings or foundations or heavy masonry should be obtainable in all parts of the county.

COLUMBIA COUNTY

Area 484 square miles. Population 51,413

Columbia County extends from the edge of the Pocono plateau south to the anthracite field and is crossed by the Susquehanna River. Bloomsburg is the county seat. Practically all parts are traversed by good highways. Railroads follow the Susquehanna and Catawissa Creek and enter the southern end of the county around Centralia.

Geologic formations exposed in the county range from the Clinton red shale formation up to the Coal Measures. The principal mineral resources are anthracite, limestone, sand and gravel, molding sand, and iron ore.

Anthracite. Coal is mined in Conyngham Township at the southern end of the county and dredged from the river near Bloomsburg and Espy. The reserves in the mountains are adequate for many years and the supply of river coal is renewed by each high stage in the river.

Limestone. The Helderberg limestone crops out for about 35 miles in two parallel bands across the county on the north side of the Susquehanna from the Montour County line to Berwick where they join. It is quarried for crushed stone and burned for lime at Alameda and Limeridge along the river east of Bloomsburg.

For many years the stone in the south band facing the flat alluvial terraces was extensively quarried. Most of the stone undoubtedly was burned for agricultural lime and used for flux in the iron furnaces at Berwick and Bloomsburg. Several small quarries were opened long ago in the north band east of Fishing Creek; quarries are few west of the creek.

The Helderberg contains a variety of limestones. Some beds of massive stone make a superior grade of lime but these are interbedded with shaly layers high in silica, alumina, and iron, and almost useless where they are thin-bedded.

Other Devonian and Silurian limestones in the county are impure and of little or no economic use.

Sand and gravel. Large deposits of sand and gravel occur on the river terraces between Berwick and Bloomsburg. They are utilized only at these two places, either because these supply the demand or because the flats are agricultural land. Sand for plaster and mortar, and gravel for concrete are produced. Reserves are large.

Molding sand. Medium-grain and fine-grain iron molding sand on the flood plain of Susquehanna River has been dug near Catawissa, and a sand reported to be excellent for light iron casting, like stove work, is dug on the terrace 50 feet above the river near Rupert. It is said to occur for half a mile along the State Highway.

Iron ore. A century ago the siliceous iron-bearing bed in the Iron sandstone of the Clinton group was mined experimentally in Montour Ridge near Bloomsburg. It was not fit for smelting. Near the Montour County line the principal layer is low grade ore 18 to 30 inches thick.

The soft variety of fossiliferous ore west of Hemlock Creek, as estimated by H. D. Rogers in 1846, might yield 40,000 tons for every longitudinal mile along each outcrop. East of Hemlock Creek Rogers estimated more than 200,000 tons of soft outcrop ore and not less than 70,000 tons of hard or calcareous, fossiliferous ore.

The fossil ore was mined long ago in Bloomsburg, Hemlock, Montour, and Scott Townships. It occurs on both sides of Montour Ridge. In Hemlock Township the ore was in two layers, an upper one 10 to 12 inches thick and a lower one 2 to 4 inches thick, separated by two feet of impure limestone. The ore in Montour Township was one foot thick. Probably the best of the soft ore was exhausted.

Building stone. The principal sources of building stone are the Helderberg limestone, Pocono sandstone, Pottsville conglomerate, and the sandstones in the Chemung and Catskill formations.

The Iron-sandstone of the Clinton formation, prior to 1880, was quarried extensively for building stone on Montour Ridge along Fishing Creek.

Rubble can be obtained in limestone quarries. Catskill sandstone has been quarried south of Catawissa, and Pocono sandstone could be quarried in the north and south ends of the county.

Shales. The Bloomsburg, Catskill, and Mauch Chunk shales are rather widely distributed and, where soft, are of value in brick making. Building brick used to be made at Bloomsburg; the only brickyard operating in the county in recent years is at Mifflinville.

CRAWFORD COUNTY

Area 1,016 square miles. Population 71,644

Crawford County is the second below the northwest corner of the State. It is all in the Upper Allegheny Area. At present only about one-half of one percent of the county's industry is mining. Half of the industry, however, is based on "imported" mine products. In 1940 its mineral reserves were chiefly oil, gas, sand and gravel. In addition it has excellent sandstone for building and masonry purposes. There are likely to be clays in the glacial deposits and more certainly shales in the bed rocks that are suitable for making brick, tile, and terra cotta. Unfortunately, a heavy mantle of glacial drift makes it difficult to find what is available.

Topography. Practically the whole county has broad, nearly level uplands, about 1,200 feet in elevation along the western edge of the county and 1,700 feet along the eastern edge. As a rule, these slope gently down 100 to 400 feet to broad, open valleys, many of them occupied by marshes or swamps. One of these, the Pymatuning Swamp, has been converted into a large lake to control stream flow on the Shenango and Beaver rivers. Glaciation made drainage changes and left a number of swamps and natural lakes, of which Conneaut Lake is an example; these furnish recreational facilities and are a distinct asset to the county.

Rocks. The outcropping rocks range from the basal Pottsville to the Upper Devonian. The Pottsville rocks, including the Sharon coal, now completely exhausted, and the Connoquenessing and Sharon sandstones are confined to the southeastern third of the county. Beneath them, according to the Second Geological Survey of Pennsylvania, the Upper Mississippian and the Burgoon sandstone are lacking. Lower Mississippian (Pocono) rocks underlie most of the county. Devonian rocks crop out in the north-south stream valleys of the northern townships.

Mineral resources. At present oil and gas are the principal mineral resources. The Drake well was drilled just south of the county boundary so that the county has shared in the oil and gas development from its very beginning. Little natural-production oil is left in the county. Future production must be almost entirely by repressuring the sands or by mining them. About 6,500 acres at the eastern end of the county are estimated to be underlain by oil-bearing sands with 55 million barrels still in the ground, of which 20 million barrels are recoverable by present methods. Possibly not more than 4 million barrels could be obtained at present prices and only by repressuring the sands. Crawford County has not been a large gas producer.

While little is known of such deposits, it is believed that search or prospecting might reveal beds of clay and shale suitable for making brick, tile, and terra cotta. Some of the sandstones, especially the Sharon and Corry, give promise of supplying local building stone, and it would not be surprising if some of the Corry, in particular, might be like the Berea stone so extensively quarried near Cleveland. Sand and gravel is abundant and should continue to be a source of income to the county.

CUMBERLAND COUNTY

Area 555 square miles. Population 74,806

The Cumberland Valley occupies the northern four-fifths of the county, floored by Cambro-Ordovician limestones and, at the north, by the Martinsburg shale. South Mountain, with its several ridges and intervening valleys, occupies the southern part of the county. Most of the ridge crests are held up by hard Cambrian quartzites. Along the southern border, joining Adams County, pre-Cambrian altered lava underlies a considerable area. The mineral resources of the county include the ores of iron and manganese, and the nonmetallic resources of limestone, sandstone, shale, and clay, diabase, phosphorus, and quartz.

METALLIC ORES

Iron. Limonite ores were extensively mined during the last century along the north flank of South Mountain from near Boiling Springs to southwest of Cleversburg, and along Mountain Creek up to Pine Grove Furnace. With few exceptions, all the old operations worked ore that had accumulated residually by the leaching of iron and manganese from overlying clastic formations and by emplacement in the clay of the deeply weathered Tomstown dolomite. The location and description of all these workings may be studied elsewhere.[1]

It is difficult to say whether all these operations exhausted the ore. Investigations by the Pennsylvania Geological Survey and the U. S. Bureau of Mines in 1943 indicate the presence of considerable ore at depth, and probably some as an extension, at the old Ege banks two miles southeast of Boiling Springs. In view of these results, it must be assumed that more ore possibly remains at other old workings. Careful exploration is needed to determine any reserves. If there are other undiscovered iron ore deposits, they would probably be limited to the same stratigraphic horizon of the old workings.

Specular hematite, associated with veins of quartz, occurs throughout most of the South Mountain area. At every place where it is known, there it too little iron to be of commercial value.

Manganese. Many of the old limonite workings in the county had manganese oxide minerals associated with the iron oxide. At a few of them there was a significant amount. The Ege and Beltzhoover banks near Boiling Springs both mined an unknown but considerable amount of manganese oxide.

Geologic investigation by the Pennsylvania Geological Survey and drilling by U. S. Bureau of Mines in 1943 in the vicinity of White Rocks, just south of the old Beltzhoover banks, has resulted in the discovery of a manganese-iron ore deposit of undisclosed size and reserves only two miles from Boiling Springs. The structural conditions, as well as the stratigraphic horizon at which the ore occurs, played an important role in the concentration of manganese and iron oxide minerals in this deposit. The structure is that of a synclinal basin, open and plunging toward the northeast along the northern flank of South Mountain. It is known that some similar structures occur along South Mountain, and it is reasonable that several similar, but smaller, structures are not known. These areas, especially, would be favorable areas to explore. It is significant that shallow pit and trench prospecting over much of the White Rocks area revealed little ore. Deeper pits, up to 30 feet, and later drilling penetrated a concealing layer of Antietam quartzite talus and exposed the ore-bearing clay.

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[1] Second Geol. Surv. of Pa. Annual Report 1886, part IV, pp. 1410-1514.

Two miles southwest of Mt. Holly Springs in another reentrant, the Wharton mine once produced manganese ore, mainly pyrolusite. This area has been partly explored with unfavorable results.

NONMETALLIC RESOURCES

Limestone. The county is well provided with limestone. Although reserves are unlimited, it would be necessary to investigate them carefully for quarry sites where stone of consistent quality could be quarried. Despite the abundance of limestone, there are few active quarries in the county and none that are very large. A small amount of building stone is produced. Much of the limestone makes fine fluxing stone; it was widely used for that purpose when iron mining flourished. The main product is crushed stone for road metal and construction purposes. Although it has never seemed practicable to erect a cement plant in this area, many of the county's limestones should receive attention if that possibility arises.

The limestone rocks form a belt six to nine miles wide across the county in a northeast-southwest direction. Along the flank of South Mountain the Tomstown dolomite is usually deeply weathered to a residual clay. Northward the Conococheague, Beekmantown, Chambersburg, and Stones River limestones floor the Great Valley. The Stones River formation has been most extensively quarried. Details of individual areas and of the separate formations are presented in another publication.

Calcareous marl occurs at several places east of Carlisle in beds ranging from one to more than four feet thick.

Sandstone and Quartzite. The crests of South Mountain are held up by the resistant Antietam and Montalto quartzites. These have been quarried locally for several purposes, including building stone, crushed stone, and sand. The Antietam is locally very white and clean, making a fine quality construction sand.

Along the northern border of the county the Tuscarora quartzite forms the crest of Kittatinny Mountain. Considerable talus has accumulated locally along the flanks of the mountain. Some of this quartzite may be of value to the silica refractories industry although no high-grade rock has been found.

Shale and Clay. The Martinsburg shale occupies all the northern part of the Cumberland Valley. At several places it has been quarried and used as a road dressing. It has also been used for the manufacture of brick. The light gray, well-weathered shales throughout this belt would probably make good building and face brick.

Clays, residually accumulated by weathering of the limestones in the southern part of the Cumberland Valley, are irregular in distribution and thickness. They are locally of excellent quality for making tile products, brick of different quality, and as a modeling clay.

Along the flank of South Mountain there are two kinds of residual clay. That which is residual from the Tomstown dolomite is usually brown and tan and could be used for brick manufacture. Locally there are pockets of white clay, as near Boiling Springs, that make excellent tile. More important, the upper part of the Antietam quartzite is commonly schistose, and this is usually weathered to a residual white clay, extensively worked near Mt. Holly Springs and Hunters Run. This clay is used as a filler in various products, as a base for insecticides, and a variety of other minor uses. There are undoubtedly untapped reserves of this clay, but careful investigation would be necessary to outline other deposits of it, unlike the other clays of the county which are very plentiful.

Phosphorus. Wavellite was mined for its phosphorus content between 1900 and 1906 west of Mt. Holly Springs.[1] The wavellite occurs as nodular masses in the Tomstown clay, associated with manganese and iron oxides. It is entirely secondary in origin, as are the metallic oxides. In 1942 work was begun near Barnitz to mine the wavellite and crush it for agricultural purposes. Any estimation of reserves is dependent upon exploration of the deposits.

Diabase. A narrow north-south diabase dike crosses the county west of Boiling Springs and New Kingston, making a low ridge. Although it has not been used, it could be used both as a building stone and crushed stone.

Quartz. Considerable quartz, most of it milky, occurs in vein form and frequently bearing specular hematite, in the South Mountain area. North of Pine Grove Furnace, a mile along Little Rocky Ridge, there is a great amount of float vein quartz which could be easily obtained. Though much of this vein quartz is milky white on the surface, when broken it shows reddish or rusty stains on fresh fracture, caused by the weathering of an iron-bearing mineral, probably gray hematite.

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[1] Stose, G. W., Phosphorus ore at Mt. Holly Springs, Penna: U. S. Geol. Survey Bull. 315, pp. 475-483, 1906.

DAUPHIN COUNTY

Area 520 square miles. Population 177,410

One hundred miles west from Philadelphia lies Harrisburg, the capital of the Commonwealth and county seat of Dauphin County, from which place radiate transportation lines by rail and highway in all directions. Susquehanna River, almost a mile wide at Harrisburg, is the western boundary of the county.

Rocks exposed include most of the geologic section from Beekmantown limestone of Ordovician age to and including Triassic sediments and intrusive diabase (trap rock). The mineral products are anthracite, crushed stone, lime, sand and gravel, and building brick and stone.

Coal. Beds of anthracite in the northern end of the county near Lykens, Wiconisco, and Williamstown have been mined for several decades and one shaft is about 1,000 feet deep. Mining has extended to a depth of 2,200 feet. Mining can continue for a long period, depending largely on labor conditions.

River coal is dredged at several points on the Susquehanna between Millersburg and Middletown, and especially at Harrisburg. The size of this transported waste from the anthracite fields is smaller than formerly, but each high stage in the river renews the supply.

Crushed stone. Sandstone and limestone are crushed for concrete aggregate and road metal. The northernmost quarry is in the gap in Berry Mountain just south of Elizabethville, and is developed in Pocono sandstone. Three quarries in the Hamilton sandstone at Rockville were idle in 1943. Quarries at Steelton and Paxtang, and near Hummelstown and Hershey are in limestone of Ordovician (Beekmantown) age. It is quarried at Steelton largely for flux, and elsewhere for building purposes and lime. Practically all the limestone in the county is in Swatara, Lower Swatara, and Derry Townships.

The limestones are in two wide bands, one extending eastward from the river at Harrisburg about 7 miles, and the other from Steelton to the Lebanon County line, where it is about 4 miles wide. The rock ranges from high calcium to high magnesium. The Helderberg limestone is not present.

Lime. Several small quarries opened for building stone and lime 100 years ago have long been abandoned. High-grade limestone is burned for lime near Highspire and at Swatara.

Sand and gravel. Deep deposits of sand and gravel on the river terrace at Highspire are being worked. There may be small deposits elsewhere along the river. Sand and gravel on many of the islands in Susquehanna River include much coal.

A crushing, screening, and washing plant at Elizabethtown produces sand and gravel from Triassic conglomerate.

Deposits of molding sand for iron casting may be present but have not been developed.

Building brick. Soft shales throughout the county are suitable for making common brick. Alluvial clay along the river was formerly used for that purpose. Ordovician shale at Harrisburg and Triassic shale at Royalton are used for making face and common building brick of various color, size, and texture.

Flagstone. Light-colored flagstone has been produced from the Hamilton formation on the north side of Little Mountain near Heckert Gap. The beds dip about 40°. The extent of the rock suitable for flagstone has not been determined.

Building stone. The local limestones were used for building the houses of some of the early settlers, particularly near Highspire, and occasional use is made of them now as building stone.

The mountain ridges in the northern part of the county are held up by resistant sandstone, in places almost quartzite. Float blocks of this rock on the mountain sides furnish good building stone. Float Pocono sandstone on Peters Mountain was used for this purpose in 1720, and float Tuscarora sandstone on Kittatinny Mountain in recent years.

Hamilton sandstone has been quarried extensively at the west end of Little Mountain north of Harrisburg for the construction of residences in Harrisburg and vicinity. Thin slabs of sandstone of irregular shape also have been obtained here for flagstone walks.

Iron ore. One of the earliest iron furnaces in Dauphin County was Victoria Furnace built on Clark Creek several miles east of the river in 1830. This was followed by Manada Furnace at Manada Gap in East Hanover Township in 1836, and later the Emmeline Furnace at Dauphin, Ellendale Forge on Stony Creek, and Cameron Furnace at Middletown. Between 1850 and 1867 the Porter, Bryan, Longnecker, Lochiel, and Wister furnaces were built in Harrisburg.

The ore used by the Victoria, Emmeline, and Manada furnaces could not have been local and is reported to have been hauled from Cornwall. The furnaces in Harrisburg smelted ore mostly from Dillsburg, York County.

Brown ore was mined about three miles east of Hummelstown, but that is the only definite statement found about the occurrence of iron ore in the county. It may be assumed that any deposits in the county are of no commercial value.

DELAWARE COUNTY

Area 185 square miles. Population 310,756

Delaware County at the southeast corner of the State is in the Piedmont Highland from 200 to 500 feet above sea level, and on the Coastal Plain. Media, with 5,351 people, is the county seat. Ship building is a leading industry. Marcus Hook is an important center of the oil refining industry. Transportation both by land and water facilitates business.

The rocks of Delaware County consist entirely of very old igneous and metamorphic rocks, chiefly gabbro, gneiss, schist, and serpentine. These are overlain along the Delaware River by alluvial deposits of clay, sand, and gravel. There are no metallic ores in the county. All of its mineral wealth is in nonmetallic resources, and these include clay, sand and gravel, the pegmatite minerals, and stone products.

Clay. There are few good residual clays in the county. Brick plants at Sharon Hill and just west of Chester use surface clay of fair quality. Clay from the Bryn Mawr terrace, a mile south of Elam, was once used for brick manufacture. There are no known clay reserves of any significance in the county.

Sand and gravel. Alluvial terrace deposits cover a zone two to five miles wide along the Delaware River. These consist almost wholly of sand and gravel. Locally these have been sporadically worked to a small extent. There are large reserves.

Pegmatite minerals. The rocks of the southwestern part of the county are cut by numerous pegmatites. This part of Delaware County forms an eastern extension of the Chester County feldspar district where mining flourished in the early part of the century. Around 1900 the Brandywine Summit Kaolin and Feldspar Company was the State's largest producer of feldspar. They also produced considerable kaolin, and really supplied the only commercial kaolin produced in this county. The feldspar of the district was probably nearly exhausted. It is likely, however, that other undiscovered pegmatites may yield considerable high grade potash feldspar, and small reserves of No. 2 spar may remain as extensions of some of the old operations.

Stone products. Bedrock for the entire county consists of gabbro, gneiss, schist, or serpentine, or close equivalents to these types. The gabbro and compact gneissic rocks are excellent for preparing first grade crushed stone for railroad ballast and road metal. Although they have not been used very extensively as a building stone, they are attractive, commonly taking a high polish and therefore having value as monumental or ornamental stone.

The schist rocks of the county have been extensively quarried for building stone. Many of the Philadelphia district's most attractive homes are built of the Wissahickon mica schist, which is durable and has a varied appearance from one quarry to another and according to the way it is trimmed and set.

Serpentine in two large areas could be used for building stone. Reserves of all these rocks are virtually unlimited.

Garnet. Garnetiferous schist was mined about 2 miles west of Chelsea in Concord Township at two places around 1905. The garnets were removed and used in the abrasive industry. Little is known about the operations. With cheaply produced artificial abrasives on the market, it is very doubtful whether garnet could be successfully mined in the county.

ELK COUNTY

Area 809 square miles. Population 34,443

Elk County is northwest of the center of the State. It is south of McKean and north of Clearfield County. The southeastern two-thirds is in the Lower Allegheny Coal Area, the northwestern third in the Upper Allegheny Area. The county is high, as the Atlantic-Gulf divide crosses the eastern part. It adjoins the High Plateau Area and shows some of the same characteristics. Eighty-one percent of the county is in timber, which is indicative of its rough and stony character. Most of it is given over to State forests and State game lands. The mineral resources are primarily coal, clay, sandstone, and limestone, in the order named. It also has a little oil and sizeable amount of gas.

Topography. The elevation is high; nearly all of the hills are above 1,800 feet, and on the anticlinal areas the hilltops range from 2,000 feet at the northwest to 2,300 feet at the southeast. The topography is of two types: a broad, gentle upland type on the anticlines, and in the synclines an intricate small-feature-type with many steep-sided ravines. The valleys range from 100 feet deep on the arches to 500 feet deep in the synclines.

Rocks. The outcropping rocks range in age from Upper Devonian to basal Conemaugh. Catskill red beds crop out only along several of the streams in Benezette Township. Pocono shales and sandstone constitute the lower walls of Bennett Branch and Clarion River. Mauch Chunk red shale occurs in the valley walls in the eastern end of the county. Pottsville massive sandstones make the upper slopes and underlie some of the upland. The Allegheny group caps the upland. Conemaugh rocks occur only in Horton Township, where 64 feet of Mahoning sandstone is reported.

The coal-bearing rocks lie nearly flat, capping the plateau along the axis of four minor synclines.

Mineral resources. Coal. Most of the Upper Freeport coal has been eroded. The Lower Freeport is thinner, but lower, and, therefore, more of it is left. The Lower Kittanning or Dagus bed is the principal coal of the county. It ranges from 2 to 5 feet, averaging 3 feet. It has been extensively mined in Benezette, Jay, and Fox Townships. It usually carries partings, but when clean is a good coal. The Clermont coal, 80 feet below the Lower Kittanning, ranges from 2 to 5 feet. It has been mined extensively in Benzinger Township and near St. Marys. The Alton (Mercer) beds contain a large tonnage of unmined coal, and are 2 to 4 feet thick.

It is estimated that there may be 55 million tons of coal more than 3 feet thick, 100 million tons of 2 to 3-foot coal, and 190 million tons of coal less than 2 feet still recoverable in the county.

Clay and shale. The clays of the county have not been well exploited and are not well known. Good flint clay occurs at the Clermont (Clarion) horizon and may be found at the Alton (Mercer) horizon. Where seen, the clay under the Lower Kittanning bed was thin. This may or may not be characteristic. Until proven to the contrary, clays and shales of the county may be assumed to have large potential value.

Hard flint and soft plastic clay mined near St. Marys are made into fire brick and shapes. Local clay and shale are used there for sewer pipe, drain tile, and flue lining. Soft shales have been the source of red building brick, and suitable material for this use occurs at various horizons.

Sandstone. The sandstones of the county are abundant. They have been extensively used for foundations and rough masonry and, in some instances, for whole buildings.

Oil and gas. Oil sands underlie the northern part of the county; the pools are small. It has been estimated that 24 million barrels of oil are physically recoverable from known fields, of which 7 million barrels are recoverable at present prices. Recent production has been about 70,000 barrels a year. The county could maintain that rate for a hundred years if all the known fields were drained of the oil estimated obtainable by repressuring.

Large areas are underlain by gas-producing strata. Gas production exceeded 7 billion cubic feet in 1921. Since then, it has gradually declined. One well in Highland Township was drilled to the Medina horizon at 7,150 feet without finding gas in the Oriskany sand.

ERIE COUNTY

Area 812 square miles. Population 180,889

Erie County occupies the northwest corner of the State. The county is highly industralized. The value of manufacturing in 1940 exceeded 165 million dollars. Mining is confined to sand and gravel, and clay for brick or tile. Coke, pig iron, iron and steel products and zinc smelting are included among its industries. It is one of the larger producers of sand and gravel.

Topography. Erie County presents several distinct types of topography. Near the shore of Lake Erie is a series of nearly flat benches representing old lake bottoms. These mark stages of standstill in lake history during the retreat of the glacial ice that opened one new outlet after another, each at lower levels than the last. Above the terraces is a plain tilted toward the lake, wide at the west, and narrow and steeper at the east. Above this sloping plain is the older slope, draining south and away from the lake, in which broad uplands slope down to wide valleys.

Rocks. The rocks range from basal Mississippian to middle Upper Devonian. The lowest rocks outcropping are the Northeast shales, which further east contain the Bradford Second oil sand. The youngest are Pocono sandstone mostly in the southeast corner of the county. The rocks are all sandstones and shales.

Mineral resources. Great deposits of sand and gravel in the old lake terraces have long been worked. Reserves are very large. The Corry and other sandstones, not being quarried now, are available for building stone. Flaggy sandstone in the Northeast formation gives excellent architectural effects. Some of the sandstones that are oil-bearing further south have been used for buildings, but the odor and stain of petroleum spoil their use. Some shales have been successfully used for making brick and tile.

Oil and gas. Gas has long been obtained from the Portage shales in a belt adjoining the lake at an average depth of 1,000 feet below the lake level. These are small wells, ranging from 10,000 to 100,000 cubic feet per day. The Oriskany sand under this county is 5 to 20 feet thick and so far has not produced either oil or gas. The Medina sandstone is thick, but although this bed has produced large quantities of gas in Ohio and New York, it has not been a good producer in this county. The porosity may be too low to hold oil or gas. The few wells drilled to these lower sands have not been encouraging, but cannot be said completely to disprove the presence of oil and gas in larger quantity in the county.

FAYETTE COUNTY

Area 824 square miles. Population 200,999

Fayette County lies in the Allegheny Mountains Area and the Pittsburgh Coal Area. It is on the south border of the State, the second county from the southwest corner. The county has long been the center of extensive coal mining and coking. It is bountifully supplied with railroads. It still contains large quantities of coal, though coal in the Pittsburgh bed is approaching exhaustion. It has practically no oil, some gas, an abundance of sandstones of high quality, much clay, including fire clay, some valuable limestone, and abundant shales.

Topography. The eastern part of Fayette County, lying in the Allegheny Mountains Area, is mostly high plateau country. It includes Laurel Hill and Chestnut Ridge. The crest of Laurel Hill is about 2,800 feet and locally reaches 3,000 feet, while Chestnut Ridge is between 2,700 and 2,800 feet elevation. The elevation of the upland between the two mountains is between 1,600 and 2,000 feet. The streams are about 1,000 feet lower, and many of the valleys are abrupt and steep. West of Chestnut Ridge the hilltops drop from 2,700 feet to 1,200 or 1,300 feet. The west side of Chestnut Ridge makes a bold escarpment facing west. From these elevations the drainage descends to 740 to 780 feet where the Monongahela and Youghiogheny Rivers leave the county.

Rocks. Some small areas of the basal Greene group of Permian age occur along the Lambert synclinal axis near Brier Hill and Cardale. The Washington group consists of 400 feet of shale, sandstone, and limestone with several non-economic coals, occurring mainly in a large area north of Uniontown and another along the Monongahela River. The Monongahela group, of Pennsylvanian age, includes 350 to 390 feet of shales, sandstones, limestones, and several coals, with the very important Pittsburgh coal at the base. This group underlies much of the central and western parts of the county. The Conemaugh group is a little more than 600 feet thick, with many thin coals and limestones, and thick, irregular beds of shale and sandstone. The Allegheny group, from 140 to 230 feet thick, includes shale, sandstone, and lesser amounts of limestone, fire clay, and coal. The Pottsville is about 200 feet thick, consisting of sandstone, shale, fire clay, and thin coals. The Allegheny and Pottsville groups crop out chiefly in the eastern part of the county.

Mississippian rocks include the Mauch Chunk shales and limestones, Loyalhanna limestone, and Pocono sandstones. These, and Upper Devonian rocks crop out on Laurel Hill and Chestnut Ridge.

Mineral resources. Coal. Coal is and will continue to be the outstanding mineral resource of the county. Original reserves are estimated to have been 7½ billion tons. Two billion tons of this have been exhausted, more than 1½ billion tons being from the Pittsburgh bed. The estimates for the beds other than Pittsburgh are based mostly on mine data, which may be far above the average thickness of the coal. An estimated 400 million tons of Pittsburgh coal remain, and from 1½ to 3 billion tons of coal in the other beds. The Pittsburgh bed consists of a main division up to 9 feet thick and a roof coal 2 to 12 inches thick when solid or 5 to 6 feet of alternating coal, shale, or clay. The Redstone, Uniontown, Little Waynesburg, and Sewickley coals are all workable locally, but all are split into two or more benches. In places they may be nearly or quite solid and up to 4 feet thick; and in some townships the Sewickley averages from 4 to 5 feet thick with only 2 to 6 inches of partings. The Waynesburg coal ranges from 2 to 9 feet thick with one or two partings. Of the lower coals, the Upper Freeport is 3 to 4 feet thick, usually with two or more partings, 1 to 2 inches thick. The "Brookville-Clarion" coal is variable, from 1 to 5 feet thick. In some townships some of the Conemaugh coals are 2 feet or more thick and form large future reserves.

The value of coal mined in Fayette County has been large; in 1920 it was more than $100,000,000. The value of coke made in some years equalled that amount. The coal changes from 60 percent fixed carbon at the west to 71.9 percent fixed carbon in the Ligonier Basin.

Oil and gas. Oil has never been important in Fayette County. A few barrels have been obtained from the Conemaugh sands and the Big Injun. Gas has come from the Big Injun and from the sands down to about 1,200 feet below the top of the Big Injun, possibly the Fifth sand. The gas is confined to anticlines in the western part of the county and to the crest of Chestnut Ridge where gas was found in the Onondaga limestone at 6,600 to 7,500 feet. Production in the county has ranged from 1 to 3 billion cubic feet a year.

Clay and shale. The clay and shale resources in Fayette County consist of: unconsolidated terrace deposits of the Carmichaels formation, shale from Devonian to Permian age, and plastic and flint fire clays. All of these have been used. In 1937 no use was being made of the Carmichaels clays and the brick plants were using shale. The plastic and flint clays have been mined and used rather extensively and should, therefore, be a worthwhile future resource.

Some of the clays are No. 1 quality, though most of them are classed as No. 2 or No. 3.

Limestone. Fayette County has an abundance of limestones ranging from those in the Washington and Monongahela groups to the Greenbrier and Loyalhanna limestones. The Loyalhanna is 50 to 60 feet thick and has long been extensively quarried and mined, and used for building stone, paving block, and curb stone and for crushed stone for concrete aggregate, road building, and railroad ballast. The Greenbrier and Benwood have been used as crushed stone, though not on as large a scale as the Loyalhanna. The Fayette County limestones are not highly valued for flux, chemical lime, or cement. Some of them might prove useful for making mineral wool, notably the Loyalhanna.

Sandstone. Sandstone in Fayette County has furnished glass sand, sand for silica refractories, crushed stone, flagstone, and for other uses, including molding sand and sand for blasting. The Homewood and Connoquenessing sandstones, especially the former, have been the principal source. Considerable sandstone has been used for building stone and flagstone, and some underground mining has been done on the Homewood. Sand and gravel have been obtained from the Carmichaels deposit and in the beds of the principal rivers or from terraces along those rivers.

Iron ore. Iron ores were once mined extensively in the county and used in the old charcoal furnaces. Six ore-bearing horizons are associated with the Pittsburgh, Mahoning, Freeport, Brookville, Mercer, and Mauch Chunk strata. These ores carry from 30 to 40 percent iron. The Mauch Chunk ore is hematite, but only 1 or 2 feet thick.

Salt. Table salt was at one time produced from Pittsburgh sandstone brines in western Fayette County.

FOREST COUNTY

Area 420 square miles. Population 5,791

Forest County, in the northwestern part of the State, is entirely in the Upper Allegheny Area. Eighty-five percent of the county is in forests, partly in the Allegheny National Forest. Little detailed study has been made of the county except for oil and gas.

Most of the county is underlain by flat-lying, massive Pottsville sandstones, which make a broad upland dissected with narrow valleys 300 to 600 feet deep. The upland is 1,500 to 1,800 feet above sea level. Allegheny River crosses the northwest corner in a broad trench 500 feet deep.

Coal. The basal Allegheny rocks and the Clarion (Pardoe) coal two feet thick are preserved in some of the hilltops in Jenks Township. The Mercer (Alton) coals are represented by one or two beds of shaly coal that are locally 3 feet thick, and underlie the higher summits east of Allegheny River. A lower coal (Sharon or Upper Marshburg), ranging up to 3 feet thick and underlying most of the higher areas, is generally not of good quality. There seems to be no prospect of mining coal commercially, but it can be dug for very local use.

Oil and gas. The county lies in the heart of the oil and gas field. That a larger acreage is not producing may be on account of the rough topography and dense timber. In addition to the Venango group of sands, this county contains the Warren and Bradford sands, and the Elk sand, included within 2,000 feet of Upper Devonian rocks. The sands having the largest production have been the Third Stray, Balltown, Cooper, and Watson. Total oil remaining is estimated to be 68 million barrels, of which 27 million barrels could be recovered if the price were high enough. At present prices, only one-tenth could be recovered by present natural methods, or 10 million barrels if secondary methods are applied throughout.

From the limited data at hand, it may be anticipated that considerable workable clay exists in the county. No flint clay has been reported. There is an abundance of sandstone suitable for general building purposes. Possibly some finer-grained and whiter sandstone suitable for better building or glass sand will be found. Shale should be abundant in the Mississippian (Pocono) which crops out on the sides and bottoms of the valleys.

FRANKLIN COUNTY

Area 754 square miles. Population 69,378

The Great Valley underlain by Cambro-Ordovician limestones occupies most of the county, trending northeast-southwest, and flanked by South Mountain along the eastern border and the ridges of the Ridge and Valley Area along the western border. South Mountain consists of a core of pre-Cambrian rhyolite and greenstone, flanked on the west by a series of Cambrian quartzites and dolomites. The ridges of the Ridge and Valley Area are held up by resistant Paleozoic sandstones and quartzites, and the intervening valleys are underlain by limestones and shales.

The rocks of the county have yielded the ores of iron and manganese, and many nonmetallic resources.

METALLIC ORES

Iron. As a southward extension of the old iron ore belt of Cumberland County, limonite ore was mined from open pits all along the flank of South Mountain from south of Shippensburg nearly to the State line.[1] There was considerable production from the vicinity of Mont Alto. All these old workings are situated in the Tomstown formation fairly near the underlying Antietam quartzite. The ore is limonite, locally associated with manganese oxides, and is embodied by the residual clay of the Tomstown. As with the area in Cumberland County, it is impossible to state the presence of large or even small reserves. It is quite possible that more ore remains at depth and as extensions of the old workings.

Limonite lump and wash ore was produced in fairly large quantities between Fannettsburg and Richmond Furnace about the middle of the 19th century but "after considerable development proved a source of expensive disappointment." Limonite was mined then also near Fort Louden and Mercersburg. Evidence is lacking whether further investigation would be justified.

Manganese. Manganese oxides are associated with the iron oxides of the iron ore belt. At only one place, English Bank, do past production and present surface indications point to a possible occurrence of manganese oxides in commercial amounts. This is just a possibility; exploration work must necessarily prove or disprove it. Bearing in mind the structural relations mentioned under "Metallic Ores—Manganese," further investigation of this large district in Franklin County may be merited.

NONMETALLIC RESOURCES

Limestone. There are abundant reserves of limestone in the county. The Tomstown dolomite, usually deeply weathered to clay, and containing iron and manganese oxides, flanks South Mountain. The Conococheague, Beekmantown, Chambersburg, and Stones River limestone formations underlie the eastern half of the Great Valley and an equally wide belt along the west shredded into narrow strips by faulting.

Although these limestones have not been quarried very extensively, they have been produced for building stone, fluxing stone, agricultural lime, and crushed stone for road metal and construction purposes. The Stones River formation has the highest average percent of calcium carbonate and so is best for making lime. If the need for a cement plant in the area should arise, an excellent product could be prepared by using the Stones River limestone, or certain pure beds of the Chambersburg and Beekmantown formations, with shale from the near-by Martinsburg formation.

Marble has never been quarried in the county, but attractive pink marble with green bands, in the basal beds of the Beekmantown, 1½ miles southeast of Clay Hill might well be prospected for ornamental stone.

Sandstone and Quartzite. The crests of both South Mountain and the mountains on the north and west are held up by hard, resistant sandstones and quartzites. The Cambrian Antietam and Montalto quartzites are white and gray; the Silurian Tuscarora quartzite is gray, and sometimes white; the Devonian Oriskany sandstone is locally very clean and white. Large talus flows of the Tuscarora and Antietam quartzites locally cover the flanks of the mountains. They may have value in the silica refractories industry. The Oriskany sandstone, if free of iron, may be used as a glass sand. Reserves of these rocks are virtually unlimited, but careful investigation of any local area is recommended to insure a uniform product.

Shale and Clay. The Clinton shale, occurring on the flanks of the mountains with ridges of Tuscarora quartzite, usually in poorly accessible areas, is suitable for making brick.

The Martinsburg shale, flooring the western half of the Kittatinny Valley, is locally well suited to the manufacture of brick and drain tile.

Clay residually weathered from the Cambro-Ordovician limestones is sporadic in its occurrence. The clays would probably be suitable for making brick.

White clay is found as pockets in the brown and yellow residual clay of the Tomstown formation in many places. It has been used for making vitrified tile.

White clay occurs also at the top of the Antietam quartzite by the weathering of schistose beds.

Barite. Small amounts of barite have been mined near Tomstown and Montalto,[1] in commercial quantities. There are no known reserves.

Stone products. In addition to the use of limestone and quartzite for building stone, red rhyolite from the southeastern corner of the county has been used locally for building. Greenstone, which is associated with the rhyolite in this part of the county, might be used to a limited extent for building. Both of these rocks are being crushed for roofing granules. Reserves of both kinds of rock are large.

Quartz. As in Cumberland and Adams counties, the rocks of the South Mountain area are cut by numerous quartz veins. South of Caledonia Park on the north side of Huckleberry Hill, quartz veins were once worked. Large tonnages of quartz could be mined from the veins in this county.

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[1] Second Penna. Geol. Survey Annual Report 1886, part IV, pp. 1410-1514.

[1] Stone, R. W., The Minerals of Pennsylvania: Penna. Topog. and Geol. Survey Bull. M 18 C, 1940.

FULTON COUNTY

Area 435 square miles. Population 10,673

Fulton County lies mostly in the folded Ridge and Valley Area. The exposed formations range from the Trenton limestone to the Coal Measures. The mineral resources of the county include coal, clay, iron ore, limestone, sandstone, and shale. Thin veins of barite occur in the Helderberg limestone at Fort Littleton, but do not have commercial interest. Transportation is entirely dependent upon improved highways, since the county lacks a railroad.

Coal. A very small part of the Broad Top coal field extends into the northwest corner of Fulton County. The coals in this field have been discussed under Bedford County and need not be considered here.

Clay and shale. Residual clays are present in Fulton County, but have undergone only minor development. Clay suitable for brick manufacture has been reported as overlying the Beekmantown limestone in the valley north and south of McConnellsburg. The outcrop of the Oriskany sandstone makes a loop about Warfordsburg at the south and about Fort Littleton at the north; it also follows along the west slope of Dickeys Mountain at the southeast. This sandstone carries a residual, white, siliceous clay in the adjoining counties where it is exposed, and may, therefore, contain similar clay in Fulton County.

The Martinsburg shale, which surrounds the valley about McConnellsburg, offers good possibilities for material for hollow and drain tile, and for brick making. The Devonian shales are distributed throughout the county; they are similar to those in other counties where they have qualities for brick making.

Iron and manganese ore. Iron ores occur in parts of nearly all of the formations exposed in Fulton County, but most of them have little economic value. Brown hematite is present in the basal part of the Mauch Chunk in some localities, particularly in Wells, Brush Creek, and Ayr Townships. It is not known to have commercial value. Nodules of brown hematite are associated with the Pocono at various places; its occurrence in economic bodies is doubtful. Scattered fragments of brown hematite from the Chemung formation were noted at many places along the outcrop, but deposits of economic interest are not known. The Marcellus shale in the Hamilton formation contains nodular iron ore. Openings had been made on this ore near Lowries Knob in Ayr Township and southward. Reports indicate it to have doubtful value. Possibly a large quantity of brown hematite but of variable quality occurs in the upper part of the Lower Helderberg in Dublin Township. Little is known regarding the Clinton ores in Fulton County. They had been prospected along Dickeys Mountain and Little Scrub Ridge, and were reported as a cellular brown hematite, very siliceous and containing not more than 38 percent metallic iron. Iron ore is associated with the limestones in McConnells Cove, but little is known about it.

The basal 50 feet of the Mauch Chunk is a potential manganese-bearing horizon and has been mined as such in Bedford County. In Fulton County, favorable structural conditions occur in the Mauch Chunk in the Oregon Creek district in Wells Township and offer possibilities for prospecting.

Limestone. The Cambro-Ordovician limestones form the floor of McConnells Cove. Numerous quarries work these limestones chiefly for road metal and agricultural purposes. Some of the beds are high in magnesia. The largest areas underlain by the Helderberg limestone are about Warfordsburg at the south and Fort Littleton at the north. Many small operations work these limestones for agricultural lime.

Sandstone. The sandstone resources in Fulton County are practically undeveloped. These sandstones have characteristics similar to their occurrence in the counties where they are being worked, and are, therefore, usable for similar purposes. The Tuscarora (Medina) sandstone makes the mountain ridges at the east; the Pocono sandstone underlies Meadow Ground Mountain, Sideling Hill, and Rays Hill; and the Oriskany sandstone may be located with respect to the Helderberg limestone.

GREENE COUNTY

Area 557 square miles. Population 44,671

Greene County in the extreme southwest corner of the State is notable for its large body of virgin Pittsburgh and other coals. It is estimated as having nearly 5 billion tons of recoverable coal over 2 feet thick. Greene County has long been a producer of gas and oil and will probably continue to produce those fuels for some time. Gas is so widely distributed that it makes the county one large gas pool. Other mineral resources are limestone, sandstone, clay, shale, glass sand, sand and gravel, and carbonate of iron. Of these only coal, oil, and gas have been important, although one sandstone invites further exploration. The surface of the county is mainly used for raising livestock today. Greene County has the present disadvantage of having no railroad crossing the county. Spur lines run into the county to serve commercial mines and to Waynesburg.

Topography. The divide between the Monongahela and Ohio valleys passes through the western part of the county with hilltops around 1,600 feet above sea level. Eastward streams reach the Monongahela near the south State line at about 800 feet and at the northeastern corner of the county at about 750 feet. On the west, the streams leave the county at elevations of 850 to 1,000 feet above sea level. Unlike some other parts of the plateau country, the hilltops are narrow and slopes more or less uniform to the narrow valleys. The valleys are so numerous that the general effect is of very hilly country, which may have had something to do with turning agriculture largely toward cattle raising.

Rocks. The surface rocks in the southwest corner of the county and thence east and north across a broad belt are the Greene group, 700 or more feet thick, consisting of sandstones, shales, limestones, and coals. Much of the valley of Wheeling Creek in the northwest corner of the county is underlain by the Washington group. The Washington group, about 200 feet thick, underlies a broad band across the eastern half of the county. The Monongahela group with the Waynesburg coal at the top and the Pittsburgh coal at the bottom is less than 400 feet thick and underlies practically all of the county; it crops out along the east side of the county and up Tenmile Creek. The upper part of the Conemaugh group is exposed in the eastern part of Dunkard Township and down river to Grays Landing. The Greene and Washington groups consist of alternating sandstones and shales, about seven thin coal beds, and a like number of thin limestones. The Monongahela group consists dominantly of limestones with several distinct sandstone beds, some shale, and five beds of coal, of which the Waynesburg and Pittsburgh are much the most important.

Mineral resources. Coal is the outstanding mineral resource with an original deposit estimated at more than 10 billion tons. Of this it is estimated that 173 million tons have been mined out or lost. Of what is left, it is estimated that more than one-half is in beds less than 2 feet thick. The Sewickley and Waynesburg beds together are estimated to have about as much recoverable coal as the Pittsburgh bed. There is something over one-half billion tons recoverable from the Freeport coal, 600 feet below the Pittsburgh bed. (See Coal Reserves.) The Pittsburgh bed is from 6 to 9 feet thick, not counting the roof coal which may contain several feet of coal, but so split up as to be worthless today. The Redstone coal locally reaches 3 feet; the Sewickley is from 2 to 6 feet thick. The Uniontown coal is thin, but locally reaches 4 feet. The Waynesburg coal is from 4 to 6 feet thick, but it has one or more thick partings that greatly reduce the value. The lower bench is locally 3 to 4 feet thick. The Washington coal is from 1½ to 4 feet thick, but split up and of little value. Other coals except the Freeport are thin and have little or no value at this time. The Freeport bed has been reported in oil and gas wells and a few core drill holes. It may prove a large future reserve.

Oil and gas are among the proven mineral resources of this county. The county is estimated to have a recoverable reserve of 5 million barrels of oil, most of which can be recovered only by secondary repressuring. It is not possible to estimate the quantity of gas left. Oil production in the county has been running between 200,000 and 300,000 barrels a year. At that rate the oil will last only 20 to 30 years; or 10 years or less if secondary recovery is not undertaken. There are still, however, large volumes of oil to be recovered when the price of oil and gas rises sufficiently to permit more expensive methods of recovery. Most of the production has come from the Upper Nineveh, Lower Nineveh and Gordon Stray sands.

Limestone is abundant throughout the county, but none of it is high grade. Some of the beds are up to 60 feet thick. It is suitable for ag-lime and some, but not all, of the limestones are suitable for road building or ballast. The sandstones of the county are abundant and though not much used have been used locally for bridge abutments and other rough structural work and have shown they are satisfactory for such uses. On the Hook Farm, 1½ miles south of Waynesburg, a fine and even-grained sandstone has been quarried in a small way. It invites further study. Certain of the sandstones of the county should be suitable for making common green glass. Clays are abundant, but not of high grade. Some pottery has been made. More abundant and widespread are the shales that are used for making brick and tile. Sand and gravel in small quantities occur along the Monongahela River and have been obtained by dredging. Ground water is abundant for an agricultural population and for small mining and industrial communities.

HUNTINGDON COUNTY

Area 895 square miles. Population 41,836

Huntingdon County lies south of the center of the State in the Ridge and Valley Area. The mountains on the boundary and several ridges within the county are more than 2,000 feet above sea level. The general level of the valleys is about 1,000 feet. The county is well served with transportation facilities. U. S. Route 22 and the main line of the Pennsylvania Railroad cross the central part. The railroad follows the Juniata River; spur lines run along some of the valleys. The county also had 440 miles of improved State highways.

Rocks. A series of northeast-southwest trending anticlines and synclines cause a repetition of the rocks in Huntingdon County, which range in age from Middle Cambrian to Conemaugh inclusive. Resistant sandstones make the ridges, and shales and limestones underlie the valleys. The chief mineral resources are sandstone, limestone, clay, shale, and coal. Thin beds of iron ore are associated with some of the formations; deposits of residual clay from shale and limestone are present and very small quantities of galena associated with calcite, occur in some of the limestones.

Coal. The northern end of the Broad Top coal field covers a relatively small area in the southern part of Huntingdon County. The field has had economic importance for many years. The coal beds are provisionally correlated with the coals in the Allegheny group and Pottsvile series of western Pennsylvania. One coal has been correlated doubtfully with the Pittsburgh bed. As many as five beds contain coal of mineable thickness. The several mines operating in recent years employ about 900 men. Large reserves remain to be mined.

Iron Ores. Up to the time that the Lake Superior iron ores became available, the thin residual deposits of limonite of Cambro-Ordovician age were mined extensively and numerous furnaces were in operation in Huntingdon County. The ore occurs as lump and wash ore mixed with clay, sand, and gravel. Along the outcrop the ore is soft and may contain over 50 percent metallic iron, but at depth it becomes hard, limy and siliceous, containing from 20 to 30 percent metallic iron and is called hard, block ore. The Marcellus formation contains up to 4 feet of iron carbonate and limonite locally; a manganiferous iron ore containing about 23 percent metallic manganese occurs at some places in the Mauch Chunk formation.

Limestone. The valleys in Huntingdon County are underlain by limestones that are adaptable for many purposes. Several quarries are working these limestones for local use as structural material and agricultural lime, for road metal, crushed stone, and cupola flux. Dolomite, with millions of tons of rock available, occurs near Spruce Creek.

Sandstone. An abundance and variety of sandstone is available. The Oriskany sandstone is an excellent glass sand. It is quarried and prepared at Mapleton. The Tuscarora (Medina) sandstone is a quartzite and serves well as ganister. Several large refractories plants located along the Juniata River are using this material. Large quantities are available from rock floes on the steep mountain sides.

Clay and shale. The Gatesburg and Oriskany formations are important sources of white refractory clays. Extensive operations are working these clays, for use principally as refractory cement and furnace lining. The larger operations are at Alexandria and Shirleysburg.

Although the shale resources are undeveloped, large reserves are suitable for making brick and tile. Of particular promise are the Devonian shales near Huntingdon and Mill Creek.

INDIANA COUNTY

Area 831 square miles. Population 79,854

Indiana County lies nearly in the center of the west half of the State. It is about half in the Allegheny Mountains Area and half in the Lower Allegheny Coal Area. Except where Conemaugh River crosses Chestnut Ridge and Laurel Hill, the surface rocks are all Coal Measures containing coal, clay, sandstone, shale, and limestone. At the present time coal mining accounts for more than two-thirds of all productive industries of the county; and with clay products and coke make a larger percent. In 1940 the coal mines of the county employed more than 7,000 men. Clay and clay products employed practically 300 men. The value of the coal mined in 1940 was $14,965,000.

Topography. The southwest corner of the county is all less than 1,400 feet and the northeast corner more than 2,200 feet above sea level. Chestnut Ridge crosses the county a little east of the center with an elevation of 1,800 feet at the south to 2,200 feet where it leaves the county at the northeast corner. Between it and Laurel Hill, the upland is 1,800 to 2,060 feet. West of Chestnut Ridge the hilltops are between 1,400 and 1,600 feet above sea level. In both areas the hilltops are sublevel over broad areas, and the surface descends rather sharply 200 to 500 feet to the valleys, which as a rule are fairly broad. This is due to the headwater position of the county and the fact that the post-glacial deepening of the valleys, so noticeable farther west, has not reached up stream to this area. Streams cross Chestnut Ridge and Laurel Hill in steep-sided and narrow valleys.

Rocks. The rocks of the county range from the Monongahela formation, preserved in the southwest corner by the Elders Ridge syncline, to Upper Devonian beds exposed in the Conemaugh gorge through Laurel Hill in the southeast corner. More than 200 feet of Monongahela shales, sandstones and limestones, with the Pittsburgh coal at the base, are preserved in the county. The Conemaugh formation with a thickness of 650 feet or more underlies most of the surface. Its most prominent beds are the Connellsville, Saltsburg, Buffalo, and Mahoning sandstones. Several thin limestones and coal beds are also present, but of little value. As the Pittsburgh bed is approaching exhaustion, most of the mineral values of the county lie in the Allegheny group, including in particular the Upper and Lower Freeport and the Lower Kittanning coals. Because of its low position, the Allegheny formation is not as well exposed, particularly the lower part, as might be wished. It is believed, however, that large reserves of the three coal beds mentioned exist in the county. The Vanport limestone occurs in the northeast corner of the county. The Brookville coal may be of value, but little knowledge exists regarding it. The Pottsville group is exposed in the two Conemaugh gorges. The Mississippian series includes the Mauch Chunk red beds up to 160 feet thick, the Loyalhanna limestone 45 feet thick, and the Pocono sandstone 1,000 feet thick. These are well exposed on the west flank of Laurel Hill anticline and where Conemaugh River crosses Chestnut Ridge. Several hundred feet of Oswayo sandstone and shale (basal Pocono) and the topmost Devonian, including about 400 feet of red Catskill (Cattaraugus), are exposed at the southeast corner of the county.

Mineral resources. Coal. The main coals include the Pittsburgh bed, the Upper and Lower Freeport, and the Lower Kittanning. The Pittsburgh bed, now approaching exhaustion, is from 6 to 8½ feet thick, not including one or two partings. The Upper Freeport is widely exposed, but variable in thickness. In some areas it is 5 feet thick, in others only 1 foot. The average for the county is more than 3 feet. The Lower Freeport ranges from 10 inches to 16 feet. It is known to be absent in some areas. Locally, as near Glen Campbell, it is very thick with several partings. It is probable that a large body of this coal is yet unmined. The Upper Kittanning is locally workable and in one area carries 1 to 9 feet of cannel coal. Most of the sections available indicate a thin coal of only distant value. The Middle Kittanning coal has a maximum thickness of 2 feet and its average is 6 inches. The Lower Kittanning has been mined extensively in the southern part of the county and occurs in other parts. Sections indicate a limited amount of coal over 3 feet thick, but a large amount of coal between 2 and 3 feet thick, and considerable coal below 2 feet. The Brookville coal is a 4-foot bed in the northeast corner of the county, and 3 to 4 feet on Blacklick Creek.

From an initial volume of nearly 7 billion tons, it is estimated that more than one-half billion tons have been mined out or lost, that 800 million tons over 3 feet thick are recoverable, 1½ billion tons between 2 and 3 feet thick, and over 2 billion tons less than 2 feet thick recoverable in the future. The coals range from 24 to 33 percent volatile matter, 58 to 67 percent fixed carbon, and 13,500 to 14,260 B.T.U., all on the as received basis.

Clay. Clays underlie the Upper Freeport, Lower Freeport, Upper, Middle and Lower Kittanning, and "Brookville" horizons. Of these the Lower Kittanning clay is from 2 to 12 feet thick and appears to be of high value. The Upper Freeport 1 to 9 feet thick seems next in value. The Lower Freeport clay 1 to 8 feet thick is third. Flint clay occurs above the Upper Freeport (Wehrum) horizon, and at the Upper Freeport, Upper Kittanning, and Mercer horizons. None appears to be of high grade.

The Bolivar flint clay, 10 to 20 feet below the Upper Freeport coal and 3 to 8 feet thick, has long been worked at Bolivar and at Salina, just over the line in Westmoreland County. It is highly probable that many of the shales in the Conemaugh are suited for brick and tile.

Limestone. The Loyalhanna limestone is exposed at the southeast corner of the county and where Blacklick Creek and Conemaugh River cut through Chestnut Ridge. It is highly siliceous, more than 50 feet thick, and suitable for railroad ballast, crushed stone, and paving blocks. The Vanport, 5 to 6 feet thick, at Hortons and Rochester Mills is doubtless of high quality but of limited outcrop. The Upper Freeport limestone ranges from 1 to 10 feet in thickness, but in most places is about 8 feet. It has from 2 to 16 percent magnesium carbonate and 36 to 89 percent calcium carbonate. The Mahoning limestone is locally 4 feet thick, as is the Ames in the middle of the Conemaugh. The Woods Run and Pine Creek limestones are 2 to 3 feet thick.

Sandstone. Sandstone in the Connellsville, Morgantown, Saltsburg, Mahoning, Butler, Kittanning, Clarion, and Homewood horizons is locally massive, thick-bedded, and will make blocks of convenient size for building. None of these beds is of high quality so far as seen. They vary in color and texture but commonly weather to a greenish buff.

Gas. Natural gas is found in quantity only on or west of Chestnut Ridge. A little gas has been found east of the ridge, but not in commercial quantity. Most of the gas comes from the northwest townships. It has been found from the First sand to the Kane sand, with the Speechley perhaps the largest producer. Gas production has ranged from one-half billion cubic feet to 3 billion cubic feet in a year. The first gas pool, the Juneau, was discovered in 1883.

JEFFERSON COUNTY

Area 652 square miles. Population 54,090

Jefferson County lies north of the center of the western half of Pennsylvania. All but the southeast corner is in the Lower Allegheny Coal Area. Coal is the most valuable mineral resource with an estimated billion tons available now. The cream of the original coal has been taken and production has declined as the thicker deposits have been mined out, but large quantities of coal 2 to 3 feet thick are left and 300 million tons more than 3 feet thick are available. Mining and quarrying in recent years has yielded more than 2 million tons of coal, a few thousand barrels of oil, about 10 billion cubic feet of natural gas, employment to hundreds of men in mining clay and making clay products, and additional men quarrying glass sand and making glass. The central and southern parts of the county are well served by railroads.

Topography. The county is a deeply dissected plateau. Ridge tops are narrow except along the northern border close to the deep and rugged valley of Clarion River. The gently rolling upland is 1,500 to 1,800 feet above sea level, and averages about 1,600 feet. The highest points are 2,160 feet only half a mile from Toby Creek 700 feet below at the northern end of Snyder Township, and 2,220 feet near the southeast corner of the county. The least altitude is 1,100 feet where Redbank Creek exits.

The major streams are entrenched 400 to 500 feet below the general upland. Wide valley floors are rare. Most valleys are narrow, especially the lower ends of those that are tributary to the major streams. Some widen toward their heads. Many roads avoid the narrow valleys and follow the upland as far as possible.

Rocks. The outcropping rocks range from about 250 feet of the lower Conemaugh group of Pennsylvanian age to the Pocono series of Mississippian age. The Conemaugh group with the Brush Creek coal and limestone underlies the hilltops in the southwest and southeast corners of the county. The Allegheny group with eight coals and clays and several sandstones and limestones, and some of the Pottsville rocks crop out in the valleys and along the anticlines in the center of the county. The Allegheny underlies most of the hilltops and some Pottsville crops out in the valleys of Redbank Creek and its principal tributaries. In the northern part of the county the Pottsville series is in the hilltops and the Pocono in the valleys of Clarion River and Toby Creek. The Pottsville is prominent throughout the northern part of the county and about 200 feet thick.

Mineral resources. Coal. Coal is the principal mineral resource, including eight beds in the Allegheny group. Most of the thick coal in the county has been mined out, so that production today is not nearly as large as in years past. It is believed, however, that there are still very large amounts of mineable coal in the county though in much thinner beds than those formerly mined. The Allegheny group, 350 feet thick, contains the two Freeport, three Kittanning, the Clarion, and Brookville coals. Locally one or more are missing.

The Upper Freeport is irregular in thickness and quality. It ranges from 26 to 52 inches in thickness and averages less than 3 feet. It has been mined extensively in Gaskill and Snyder Townships.

The Lower Freeport is the most important coal in the county. In areas where it was 6 to 7 feet thick, most of the coal has been mined out, but much coal averaging 4 feet thick remains. The Upper Kittanning coal is rarely over two feet thick. The Middle Kittanning is best developed in Knox Township where it is 3 to 4 feet thick. The Lower Kittanning is persistent and averages 2 to 3 feet thick in most of the county.

The Clarion and Brookville coals are fairly persistent but thin. Only locally is commercial mining undertaken on them. The Upper Mercer ("Brookville") coal is 4 feet thick at Conifer, and is mineable under a considerable part of the county. It is thin and split up at Brookville. It lies about 80 feet below the Vanport limestone and 130 feet below the Lower Kittanning coal.

Oil and gas. Oil has been found in two small pools in the northwest corner of the county. Considering the widespread drilling for gas without encountering more oil, the prospect for additional pools is not encouraging. The western part of the county appears to be almost one large gas pool. Gas has come mostly from the sands between the Murraysville and Kane, with the Speechley a large producer. There is no known diagnostic relation of the gas pools to the structure, though the chances of getting gas appear to be a little better on the anticlines than on the synclines, and the anticlines may produce larger wells.

Clay and shale. Clay and shale stand second in the immediate and future value of minerals of the county. The Lower Kittanning clay averaging 6 to 8 feet thick, but ranging from 3 to 20 feet, leads in quantity and quality. Nearly as thick and also of good quality is the Brookville clay. The Mercer clay averages 2 to 3 feet thick, but ranges from one-half to 16 feet. It is also important. The Upper Freeport and Middle Kittanning clays average 4 to 6 feet thick, but range from 1 to 15 feet. The clays under the other coals are from 3 to 10 feet thick locally. On the whole, it would appear that this county is amply provided with clay for brick, tile, or terra-cotta. Flint clay of high quality exists in the Mercer-Brookville horizon and possibly at others, but has not yet been developed. The Mercer clay as a rule crops out in forested area and at the foot of slopes where it is likely to be hidden by talus. More than 400 men are employed in the brick and tile industry in the county, and resources are here for indefinite expansion. The shale resources are also abundant for a variety of uses.

Sandstone. Little use has been made of the sandstones in the county except in the northeast section where there has been extensive quarrying of glass sand in the general region of Falls Creek. The sandstone ranges from 25 to 50 feet thick. It is nearly white and has been correlated as the Homewood. Several of the sandstones, especially the Mahoning, Homewood, and Connoquenessing, appear to be suitable for use for massive masonry or possibly for fine building purposes. The Homewood has been quarried in the northern part of the county and used in Brookville.

Limestones. The limestones of the county as a rule are thin, and only the Vanport gives promise of immediate value. While of good quality, it ranges from 3 to 10 feet but averages only 5 feet in thickness, which reduces its value as compared with other areas where the limestone is thicker. It has 93.5 to 96.5 percent calcium carbonate. The Vanport limestone is lacking in Knox, Pine Creek, Winslow, and Eldred Townships and all but the southeast corner of Union Township. The other less important limestones are the Johnstown, Lower and Upper Freeport in the Allegheny, and the Mahoning, Brush Creek, Woods Run, and Ames in the Conemaugh. All these may be of use locally.

Sand and gravel. Sand and gravel are not abundant in the county, but many of the streams and local flood plains are covered with alluvium that should furnish some.

Iron ore. Iron ore was formerly mined from the Buhrstone horizon at the top of the Vanport limestone. It ranges from a few inches to 2 feet thick and has about 34 percent iron. It was formerly used near Corsica and Milton. It has no immediate value.

JUNIATA COUNTY

Area 387 square miles. Population 15,373

Juniata County in the south-central part of the State is about 10 miles wide and 50 miles long. It stretches between Tuscarora Mountain on the south and Shade, Blue, and Blacklog Mountains on the north, from the Susquehanna River above Liverpool to Waterloo, a hamlet 10 miles southeast of Newton Hamilton. Juniata River and the Pennsylvania Railroad cross the county from Lewisburg Narrows to Thompsontown. Principal highways are Routes 22 and 322 along Juniata River, Route 35 lengthwise of the county, and Route 75 from Port Royal to Waterloo.

The oldest rocks are Cambro-Ordovician limestone on Blacklog Creek in Lack Township and the youngest are undifferentiated Upper Devonian sandstones and shale. This section includes Trenton and Helderberg limestone, Tuscarora quartzite, Oriskany sandstone, and Clinton iron ore.

Limestone. The Helderberg limestone extends in two continuous bands across the entire county from northeast to southwest. Many small quarries were opened in the previous century and the stone burned for lime. In recent years very little stone has been produced, mostly for road metal. There is considerable variation from massive to shaly, high calcium to high silica stone. Therefore, any development should be preceded by careful investigation.

The other limestones are of no importance.

Ganister. Tuscarora quartzite float occurs along the east boundary of the county and on the several ridges that make the northern boundary, but the only places where it is near a railroad are in Lewistown Narrows and between Mexico and Thompsontown. Refractory brick are made at Vandyke, using floe rock stripped from Tuscarora Mountain. At the southern tip of the county 80 percent of the floe is reported usable for silica brick; reserves of ganister cover long stretches of the mountains. This quartzite may be used also for building stone and crushed for road metal.

Iron ore. Until 1888, when mining ceased, several thousand tons of Clinton iron ore were mined monthly and sent to local furnaces. Openings were made on the ore beds the whole length of the county, but the principal mines were within a few miles of the river.

The Clinton ores were known as the Sand Vein and Danville beds. The Sand Vein in places was 12 to 24 inches of good ore, carrying 40 percent iron; in other places it was so siliceous as to be worthless. The Danville beds ranged from 2-inch seams of lean ore high in phosphorus to a bed 9 inches thick and carrying 45 percent iron.

Both hard and soft fossil ore were mined by drifts and slopes. Most of the beds stand at high angles but in some places the dip is low.

Reserves of iron ore cannot be computed with present data. The beds are thin, much of the ore is lean and in places may be lacking; nevertheless, there must be considerable tonnage of ore along more than 125 miles of presumed outcrop of the iron-bearing beds.

Sand and gravel. Deposits of sand and gravel may be looked for on the flats and terraces along Juniata River and Tuscarora Creek.

LACKAWANNA COUNTY

Area 454 square miles. Population 301,243

Though anthracite is the foundation of the county's large industrial development, manufacturing today far exceeds in value the anthracite produced, and is likely to increase continually. In 1937 about half of the working population was employed in the coal mines. Textile products lead among manufactured goods. The population is largely confined to the immediate valley of the Lackawanna. Scranton, the county seat, has a population of 140,404. The county stands fourth in the State in density of population.

Topography. The county is readily divisible into three parts: 1. the Northern Anthracite coal basin following the Lackawanna River and bounded by an inner ridge of Pottsville sandstone and an outer ridge of Pocono sandstone. The north ridges rise to 2,200 feet in Bald Mountain. 2. North of that the various units of the Upper Devonian result in a hilly upland with the hilltops 1,200 to 1,500 feet above sea level and gentle slopes to open valleys 100 to 400 feet deep, containing several ponds. 3. South of Lackawanna Valley, the rim rocks make Moosic Mountain 2,000 to 2,300 feet high. South of that the flat-lying Upper Devonian sandstones and shales floor the Pocono Plateau at elevations of 1,800 to 2,000 feet, with hills rising to 2,300 feet.

Rocks. The exposed rocks range from the Coal Measures to the Honesdale sandstone of the Upper Devonian. On the Pocono Plateau these beds are as follows:

	Feet
Mount Pleasant red beds	400
Elk Mountain sandstone	75
Cherry Ridge red beds	275
Honesdale sandstone	600

The Coal Measures range from 307 feet, with 20 feet of coal at the northeast, to 282 feet with 13 feet of coal at Carbondale, and from 633 feet with 67 feet of the coal at Scranton, to 816 feet with 85 feet of coal further west. The coal basin is single but divided by rolls into several sub-basins.

Mineral resources. Coal. Anthracite is the outstanding mineral resource. The section at Scranton shows:

Bed	*ft.*	*in.*	*Bed*	*ft.*	*in.*
Olyphant	8	8	New County	4	2
Richmond	5	8	Clark	6	6
Diamond	9	8	Dunmore #1	5	6
Rock	6	1	Dunmore #2	4	
Baltimore ("Big Bed")	11	6	Dunmore #3	3	

Of the original 2,200,000,000 tons of coal in the county, it is estimated 1,563,000,000 tons have been exhausted. Of the remainder, it is estimated that 427,000,000 tons should be recoverable. That assumes that the same percentage of recovery as obtained in 1922 would continue to the end. If in any way a larger percentage of recovery could be obtained, the life of the field would be extended.

The Pottsville, Pocono, and Mauch Chunk sandstones yield an endless abundance of building stones and have been quarried and used rather extensively in the county. These rocks are also used for crushed stone. Sand and gravel of glacial or river origin occur abundantly in the valleys. The density of population and the use of the ground for other purposes interferes somewhat with their use. Clay and shale are not as abundant or useable as in the bituminous fields. The under clays are thin or slaty or often lacking. The Coal Measure shales are too often slaty or carbonaceous to be used. Outside of the coal area, the Mississippian and Devonian rocks increase in their percentage of sand eastward and the shales of this area are often too sandy for brick making. Doubtless, less sandy beds can be found. The county had no ceramic industries in 1940. Special attention should be given to the shales just below the Pocono sandstone.

LANCASTER COUNTY

Area 945 square miles. Population 212,504

Lancaster County is bounded on the west by the Susquehanna River and on the south by Maryland. The northern part is in the Triassic Area, the middle in the Piedmont Lowland, and the south end in the Piedmont Highland. The general elevation is between 300 and 600 feet. The greatest elevations are 1,100 feet on Welsh Mountain, 1,160 on South Mountain, and 1,200 feet on Furnace Ridge north of Penryn.

Lancaster, the county seat, has a population of 61,345. Railroads, U. S. Routes 20, 222, and 322, and 1,074 miles of improved State highways furnish ample transportation.

Rocks. The rocks of Lancaster County range in age from pre-Cambrian and early Paleozoic metamorphic rocks (schists, gneisses, serpentines, and quartzites) in the southern part of the county, to Cambro-Ordovician limestones and shale in the middle, to the brown sandstone and shale and the diabase intrusions of Triassic age in the northern part. The stratigraphic and structural relations of all these rocks are complex, especially in the southern part of the county. There is considerable faulting of the rocks, and many of the faults are thrusts. Details of the geology may be consulted in the references.

The varied rocks of this county have produced as great a variety of valuable mineral resources during the past 250 years as any other county in Pennsylvania, and possibly any other similar small area in the United States. These mineral resources, many of which still remain as reserves of different size, include the ores of iron, chromium, nickel, lead, zinc, magnesium, and silver, and the nonmetallic products of limestone, sandstone, slate, clay, sand and gravel, and others. These resources are described, especially with a view to their future production.

METALLIC ORES

Iron. Limonite was mined at more than 25 separate localities in Lancaster County during the last century. The large Chestnut Hill mines near Silver Springs produced 25,000 tons of brown ore a year over a period of many years. These were the largest mines, but others produced considerable ore, and all of them together comprised a mining industry of significant magnitude. Today all the mines are idle, though ore may remain in limited quantities at depth and around the edges of the old workings, thus constituting reserves for future use. Such reserves are only potential until some form of physical testing, like drilling, is applied to the areas in question.

The limonite ores occur in association with the Vintage dolomite, Ledger dolomite, and to a lesser extent with the Conestoga and Conocoheague limestones. With few exceptions the deposits that were worked occurred near the contact of the Antietam sandstone with the overlying Vintage dolomite or along faults in the limestone rocks. Any iron ore deposits that have not been indicated previously might be found by bearing these features in mind.

Chromium. Chromite was mined from the serpentine rocks of Fulton and Little Britain Townships till 1882, at which time the Wood mine, the largest producer, ceased operation. Prior to the Civil War, and from 1828, when chromite was first mined in the area, 100 percent of the world's chromium supply came from the district. The Wood mine was unwatered in 1937 and examined carefully; practically no ore remained. Apparently little ore remains at the other old operations in the district. The possibility of chromite reserves being discovered in the district is fair. The results of exploration based on geophysical investigation of the area around the Wood mine in 1941 were not favorable. However, the lens-like character of most of the deposits and the probability that they are magmatic segregations makes it evident that similar concentrations may be expected elsewhere in association with the serpentine rocks. Detailed geophysical work, using improved methods, is probably the only way in which other deposits of chromite can be indicated. Small amounts of placer chromite occur in the flood plains of the small streams which flow through the serpentine area.

Nickel. The Gap Nickel Mine, 4 miles southwest of Gap, first operated as a copper mine, working sporadically from before 1740 to 1852. In the latter year nickel was discovered in the slag and the mines were operated for the nickel content until 1893. The ore mineral was chiefly nickeliferous pyrrhotite disseminated and locally concentrated in shoots in a large mass of peridotite infolded in the metamorphic schistose rocks of the Mine Ridge complex. For many years about 7,200 short tons of ore was the average production, and the mine was responsible for more than a tenth of the world's nickel until operations were forced to cease because of more cheaply produced nickel imported from New Caledonia, and Sudbury, Ontario.

Because of the nature of the ore occurrence and the fact that the average tenor of the mined ore was between two and three percent, it is probable that small reserves of lower grade ore remain as an unmined extension of the old workings. The area adjoining the workings was carefully explored in 1942 and any reserves that exist are known to the owners.

The possibilities of unfound deposits of nickel ore in the county are confined to peridotite rocks like those at Gap Mine. Several areas where peridotite or serpentinized peridotite occur are briefly discussed under the title Metallic Mineral Resources.

Magnesium. Dolomite was quarried for the purpose of making magnesium products near Lancaster (Schreiner Station), and near Mt. Joy by two different companies for a short time. In both instances, the rock was not suitable. Uniform low-silica dolomite of good grade can be utilized by several different processes for the production of magnesium. The Ledger dolomite and the Vintage dolomite both occur extensively in the broad central belt of limestone rocks in Lancaster County (see geologic map), and some portions of each formation consist of high-grade dolomite. In many cases, good dolomite is interbedded with high-calcium limestone or high-silica limestone and dolomite, thus preventing easy quarrying of a uniform product. This factor should be recognized, and careful exploration carried out wherever operations may be contemplated.

A small amount of magnesite has been mined from the serpentine rocks near the Maryland line. Small pockets may be found.

Lead and zinc. Silver-bearing galena was mined at the Pequea Mine, 1¼ miles north of Marticville and 1½ miles east of Conestoga, in 1862. Four veins, 3 to 6 inches wide, were prospected and a small amount of good ore removed. Apparently there was insufficient ore to make further mining worthwhile.

Zinc ore was mined about one-third of a mile northeast of Bamford, five miles northwest of Lancaster, in 1855, and from 1873 to 1877. The last sporadic mining ceased in 1883 for two reasons: lack of ore and mechanical difficulties. The mining at Bamford has been well described.[1] From the descriptions it is clear that the ore was low grade, and it was necessary to mine it with the greatest economy. Any future production of zinc ore from this locality is dependent entirely upon careful exploration of the immediately surrounding area, and on the basis of the past operations it is doubtful whether much money should be expended on such exploration.

NONMETALLIC RESOURCES

Limestone and dolomite. Almost the entire middle part of the county is underlain by limestone or dolomite of Cambrian and Ordovician age. Many quarries have been opened in the Beekmantown limestone, Conestoga limestone, and Ledger dolomite, and some in the Conococheague limestone and Vintage dolomite. The quarried rock is used as crushed stone for road metal and construction, fluxing stone, occasionally as building stone, and in the production of agricultural limestone and lime products. Details of the limestone and dolomite rocks are presented elsewhere. If there is need for other new operations, the reserves are large and available with little initial work to remove overburden.

The Ledger dolomite is an almost pure dolomite at many places. Where it is free of much silica and homogeneous, it may serve as a source of magnesium and magnesia products as well as excellent fluxing stone.

Sandstone. The Chickies quartzite crops out in or underlies the hills from north of Rohrerstown and Mountville to Marietta along the Susquehanna River. It is present in the same manner surrounding the Mine Ridge complex in a narrow belt of U-shaped hills with the apex at Quarryville and the open end toward Christiana and Atglen. The Chickies is friable and easily crushed down to its component silica grains at some places, such as at Oyster Point where it is quarried and crushed to be used in construction work. In the western part of the Mine Ridge area the Chickies has weathered to a clean homogeneous medium-grained white sand which covers many of the smaller roads. At most places it is a hard quartzite rock, and it has been quarried in this typical form on Chickies Rock, near Marietta. Large reserves of the Chickies quartzite are available.

The Triassic brown and red sandstone underlies most of the hilly land in a three-mile zone along the north and northeastern border of the county. At several places it has been quarried for building stone. Large reserves are available.

Clay and shale. There is abundant clay residually weathered from the limestones in the county. Much of this clay is well suited to the manufacture of brick, and it is being used by the three operating brick companies in 1944. The clay is of variable thickness, lying on top of the irregularly weathered surface of the limestones. By far the best clay of this type is that weathered from the Conestoga limestone.

The Cocalico shale, underlying a large area around Manheim, weathers to a good brick clay of different colors. Some of the soft red shales in the Triassic rocks of the northern part of the county should also be suitable for brick making. There are large reserves of these clays and shales.

Just west of Narvon, along the north slope of Welsh Mountain in the easternmost part of the county, schistose layers of the Chickies quartizite, or the Harpers phyllite, have weathered to a mica-speckled gray and white clay which is used as a refractory and filler. At this horizon along Welsh Mountain there are probably other reserves of this type of clay.

Mica schist. The Chickies formation is essentially a mica schist near Greentree, about 3 miles east of Quarryville, where it is quarried for building stone of high quality. There are unlimited reserves of fine building stone from the Chickies formation, and it is possible that some of the Wissahickon and Peters Creek schist, which underlie most of the southern part of the county, can be used for the same purpose.

Serpentine. Several quarries have produced serpentine for road metal on minor roads in the county, and one has produced a mixture of serpentine and peridotite for use as a magnesia-bearing flux. There are large reserves of serpentine in Fulton Township, but there is very little homogeneity to the quarried product. Chrysotile, an asbestos mineral of high grade, has been taken from the serpentine in very small quantities near White Rock, Little Britain Township. Although it is generally too soft, serpentine has been used as an attractive building and ornamental stone.

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[1] Second Pennsylvania Geological Survey, vol. CCC.

Slate. The Peach Bottom slate underlies a 7-mile long, half-mile wide belt of hills from Fairmount to Peach Bottom in the southern part of the county. A lustrous blue-black roofing slate of excellent quality was quarried from as many as 11 openings between 1800 and about 1880. As a roofing slate, the Peach Bottom product has no superior. It was also used for other minor purposes. In 1910 there was renewed activity, but since then the old quarries have been idle.

Much of the slate belt is schistose in character, and tremendous waste piles at the site of the old operations indicate the difficulty of quarrying a uniformly good product. Nevertheless, there are large reserves of slate in this district, and it is reasonable to assume that much of the slate is of excellent quality.

Trap rock (diabase). Basic igneous intrusions, as sills and dikes, are common in the Triassic rocks of the northern part of the county. Most of the high hills are underlain by diabase or trap rock. At the outcrop this rock frequently weathers to large, rounded, black to rusty boulders. They have served in several instances as building stone, and the freshly crushed rock makes excellent railroad ballast and road metal.

Several diabase dikes cut across the southern part of the county, and one of these has been extensively quarried at Safe Harbor.

Molding sand. On one of the old river terraces at Washington Boro a small operation has removed molding sand of fair quality. It is possible that other deposits may be located along the river terraces.

Gravel. The various terraces of the Susquehanna River from Falmouth to Creswell are composed of gravel and sand. By testing, it is reasonable to expect gravel deposits of good quality may be developed along the river.

Building and ornamental stone. The use of limestone, sandstone, schist, serpentine, slate, and diabase as a building stone has been mentioned. In addition to these rocks, there are others which have either been used in a small way or are attractive and durable enough to be used. A beautiful ornamental stone can be prepared from the limestone breccia, of Triassic age, which crops out near Bainbridge. This rock also makes attractive terrazo flooring when crushed and cemented together. Some of the granitic rocks of the Mine Ridge complex between Quarryville and Christiana, and from the northern tip of the county might be suitable for monumental or ornamental stone.

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LAWRENCE COUNTY

Area 367 square miles. Population 96,877

Lawrence County, in the center of the west line of the State, lies entirely within the Lower Allegheny Coal Area. Because of excellent transportation and the presence of limestone, sandstone, and clay of good quality, the county ranks fairly high in the mining industry and in certain mineral-based industries such as lime, cement, pottery, crushed stone, and cut stone. The county also produces some oil and gas.

Topography. The relief of this county is small. The hilltops are broad with generally gentle slopes to wide, open valleys. Locally the hills are abrupt and in the southern part of the county adjoining the main streams the surface is broken into narrow valleys with steep slopes and narrow divides; but in general a nearly level type of topography prevails. The hilltops in the western part of the county range from 1,100 to 1,300 feet above sea level, rising toward 1,400 feet at the eastern edge of the county. The lowest point of the county where Beaver River leaves is 745 feet above sea level. Drainage changes due to glaciation are responsible for some of the topography. Thus, the upper valley of Slippery Rock Creek is wide and open. The lower valley, 300 feet lower at Wurtemburg, is a steep-sided gorge because the creeks formerly flowed west to the Beaver River near New Castle and, that outlet being blocked by the glacier, the stream was turned southward, cutting its present narrow gorge.

Rocks. The rocks of the county range in age from the Mississippian Pocono sandstone, which underlies the valleys of the Mahoning and Shenango Rivers in the northwestern part of the county, to the Pennsylvanian Conemaugh shales and sandstones, which cap some of the hills in the southern part. The Pottsville rocks underlie most of the stream valleys. The Allegheny rocks underlie about fifty percent of the county.

MINERAL RESOURCES

The chief mineral resources are clay, coal, limestone and sandstone. All of them are used on a fairly large scale.

Clay. Clay occurs under all the coal beds. Usually the clay under the Lower Kittanning coal, 4 to 10 feet thick, is the most important. This clay often has 4 to 5 feet of soft, plastic clay, underlain by 5 feet of hard blue-gray sandy clay. Clays from 1 to 10 feet thick occur under the Upper Freeport and Middle Kittanning coals and from 1 to 5 feet thick under the Clarion and Brookville coals. The Lower Freeport clay has a maximum thickness of 3 feet.

Besides the under clays, which constitute some of the most important mineral resources of the county, there are alluvial clays in the flood plains of most of the streams. Shales in the Allegheny rocks are locally suitable for making brick and terra cotta. Common, face, and paving brick, refractory products, chinaware, pottery, and sanitary ware are the principal clay products. Reserves are sufficient to assure continued production for a long time.

Coal. The Upper Freeport coal is of little value. It underlies only a few hilltops on the south edge of the county and its thickness is irregular. Locally it is 6 feet thick; it has an average thickness less than 2 feet. The Lower Freeport, commonly thin and dirty, is 6 feet thick and excellent in Little Beaver Township. It underlies large hilltops. Some of these areas might offer opportunities for stripping, though in places the coal is immediately overlain by the massive Butler sandstone. It has its best quality in Little Beaver Township. The Middle Kittanning (Darlington) coal underlies a much larger area than the preceding coals. It averages 2 feet in thickness and is very clean. Locally, it is cannel. There have been many small mines on it in the past. The Lower Kittanning has been opened at many small mines. It ranges from 12 to 46 inches and averages about 2 feet in thickness. The Pardoe (Brookville) coal is 42 to 48 inches thick and mined at Volant. Most of it is thinner, however, and it is rarely mineable. The lower coals are generally thin or dirty and of no commercial importance, though mineable locally for domestic use.

Limestone. The Vanport limestone forms a large lense in this county up to 20 feet thick. It is well developed over much of the county. East of Beaver River where the bed is 15 to 20 feet thick, the upper 10 to 20 feet is hard, blue limestone. The upper and middle sections of the limestones range from 91 to 97 percent calcium carbonate, the lower part from 81 to 90 percent. The limestone is both quarried and mined for portland cement, lime, fluxing stone, crushed stone, and pulverized for agricultural use. In the presence of this fine bed of limestone the other beds have little or no immediate value except for local use. The Upper Freeport is more than 7 feet thick in Perry Township but only 5 feet of the bed is limestone. The Lower Freeport and Mercer beds are thinner.

Sandstone. The Homewood has long been quarried in this county. Locally, it is a cliff maker, as around Ellwood City, and ranges from 20 to 60 feet thick. It is massive and suitable for producing large dimension stone. So is the Connoquenessing sandstone, which is 80 to 100 feet thick and massive. It has been extensively quarried at Neshannock Falls. Quarries in both formations could be opened at many places. The Buffalo, Butler, Kittanning, and other sandstones are more or less massive and could be used for building stone.

Oil and gas. The oil and gas sands of Lawrence County consist of the Slippery Rock bed, possibly one of the Shenango sandstones, the Berea, the Murraysville, and the Thirty-foot, which is 430 feet below the top of the Berea. Most of the pools have been small. The Berea is practically the only persistent productive sand for both oil and gas. In recent years, Lawrence County has been credited with 10 to 15 thousand barrels of oil a year. Reserves are estimated at 4 million barrels recoverable under present conditions.

Iron ore. The Buhrstone iron ore, occurring on top of the Vanport limestone, was mined by stripping on Spangler Run in Shenango and Wayne Townships prior to 1890 and used at the furnaces in Mahoning Valley. At the outcrop it was limonite carrying an average of 50 percent metallic iron. In one place the bed was 22 feet thick but mostly it was 3 to 4 feet. This occurrence might warrant investigation.

LEBANON COUNTY

Area 362 square miles. Population 72,641

Lebanon County is mostly in the great Kittatinny Valley, east from Dauphin and north of Lancaster County. The upper or north end is on Stony Mountain and the lower end on South Mountain. Kittatinny Mountain, which crosses the northern part, is held up by the hard Tuscarora sandstone turned on edge, and the other northern ridges by Pocono and Pottsville sandstones. Their crests are 1,200 to 1,600 feet above sea level, in comparison with the general elevation of the great valley at 400 to 600 feet.

The principal class of industry is metals and metal products, valued in 1940 at $25,000,000. Mine and quarry products in the same year were valued at $5,000,000.

Rocks. The rocks of Lebanon County range in age from pre-Cambrian granodiorite, which occurs in the southeastern corner of the county, to coal-bearing Carboniferous rocks along the northern border and

Triassic sandstones and shales with diabase intrusions along the southern border. Cambro-Ordovician limestones, and the younger Martinsburg shale, underlie most of the county. The northern end of the county lies in the Anthracite Area forming a zone 5 or 6 miles wide in which Silurian, Devonian, Mississippian, and Pennsylvanian rocks are exposed. Just south of Jonestown a lava flow and several altered diabase dikes are associated with the Martinsburg shale.

The rocks of Lebanon County include a variety of mineral resources. Although they are produced only as a by-product incidental to the mining of magnetite iron ore at Cornwall, the precious metals, gold and silver, as well as abundant copper and a small amount of cobalt are metals that are not mined at any other place in the State. There are large reserves of nonmetallic resources like limestone, sandstone, shale and clay, and trap rock.

MINERAL RESOURCES

Iron. Magnetite, occurring as a replacement of Cambro-Ordovician limestone and limy shale beds adjacent to diabase intrusions of Triassic age, has been mined at Cornwall since the middle of the 18th century. Open cut and shaft mining of these large deposits, located five miles south of Lebanon at the southern edge of the Lebanon Valley, produce high-grade magnetite ore in quantities that make Cornwall one of the important iron ore districts of the United States. Details of the deposit are considered elsewhere.[1] Exact reserves of ore in the Cornwall district cannot be listed, but they are sufficient to maintain operations for many years.

Reserves of gold, silver, copper, and cobalt are also contingent upon the reserves of magnetite at Cornwall.

Limestone. The southern half of the Lebanon Valley, from Cornwall to just north of Lebanon is underlain by the Conococheague, Beekmantown, and "Annville" limestones (from south to north). All of these limestones have been quarried for the several purposes of fluxing stone, agricultural limestone and lime products, crushed stone, and building stone.

The "Annville" limestone is by far the most important. About 300 to 400 feet of high-grade limestone (with an average of more than 96 percent calcium carbonate) extend from Millardsville and the vicinity of Myerstown to the eastern edge of the county through Avon, and thence from Cleona to Annville to Palmyra at the western end. The limestone dips south at 30° to 90° angles. Many quarries have been opened on this belt. From these operations it is known that the high-grade limestone extends, in some cases, to a depth of 500 feet. It is obvious that very large reserves of this quality stone are available, although part of it may be recovered only with difficulty.

Some of the upper beds, in the hanging walls of the quarries, are high-magnesian. Much of the Conococheague formation also is high in magnesium carbonate. It is doubtful, however, that a sufficiently homogeneous high-grade dolomite occurs in the county to be significant in the production of magnesium or magnesia products.

The Tomstown dolomite, deeply weathered, underlies a narrow arcuate belt flanking the mass of granodiorite in the southeastern tip of the county, and is generally of no value. Numerous limestone interbeds in the Martinsburg shale sequence in the middle part of the county have been used locally by farmers to burn lime. The Onondaga limestone is exposed in an old quarry at Swatara Gap, and the Helderberg limestones are poorly exposed along Swatara Creek in the north. These have little or no value here.

Sandstone. The crests of the ridges crossing the county along its northern border are all held up by resistant Paleozoic sandstones, including the well-indurated gray Tuscarora sandstone, the white and gray Hamilton and Upper Devonian sandstones, the tan and brown Pocono sandstone, and the gray Pottsville sandstone and conglomerate. Of all these rocks there are unlimited reserves. The hard sandstones may be suitable for ballast or road metal, and some or all may have limited value as building stone. The Upper Devonian sandstones may have some value as flagstones. In most cases transportation facilities would be poor and quarrying conditions difficult.

Triassic brown and red sandstone has been quarried for building stone from several places near Mount Gretna. The belt of Triassic rocks extends across the southern border of the county and doubtless there are other localities where Triassic sandstone of fine building quality could be obtained.

White sandstone of good quality for construction purposes caps the northern ridge of the Bunker Hills, about a mile south of Jonestown. It has been crushed for building sand. There are small reserves of this sandstone which could be quarried along the ridge crest.

Shale and clay. Mauch Chunk shale, red and soft, and suitable for brick manufacture underlies the valley of Stony Creek at the north end of the county.

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[1] Spencer, A. C., Magnetite deposits of the Cornwall type in Penna.: U. S. Geol. Survey Bull. 359, 1908.

Callahan, W. H., and Newhouse, W. H., A study of the magnetite ore body at Cornwall, Penna.: Econ. Geol., vol. XXIV, pp. 403-411, 1929.

Hickok, W. O., 4th, The iron ore deposits at Cornwall, Penna.: Econ. Geol. vol. XXVIII, no. 3, pp. 193-255, 1933.

The Reading Railroad line is in this valley too. South of this valley, and between Second Mountain and Kittatinny Mountain, there is a succession of Catskill red shales, Middle Devonian shales and Bloomsburg red and green shales, all of which might be used to make brick. All of these shales are available in unlimited reserves.

The Martinsburg shales, underlying the northern half of the Lebanon Valley have been quarried at several places for the purpose of road dressing. These shales would also probably make good brick.

Triassic red shales associated with the brown and red sandstone in the southern part of the county have been used elsewhere for making brick. These shales may also be so developed in the Cornwall-Mt. Gretna district.

Residual clay from the various limestones covers the southern part of the Lebanon Valley. Although it is extremely pockety, it makes excellent brick and could probably be used for pottery. It has been worked north of Avon.

Trap rock. A coarse-grained, basic igneous rock was quarried about two miles south of Jonestown, mostly for ballast. There are several trap dikes south of Jonestown in addition to the widespread Triassic diabase intrusions along the southern part of the county, all of which can be used for railroad ballast, road metal, or building stone. Reserves are unlimited, and the residual diabase boulders accumulated along the slope of South Mountain are easily available. Although the basal part of the "lava" beds in the Bunker Hills area, south of Jonestown, is attractive with included limestone fragments, it is doubtful whether it would make a durable building stone.

Coal. Coal Measures are exposed in the synclinal valley between Sharp and Stony Mountains along the northern border of the county. This is part of the apex of the southwesternmost extension of the Southern Anthracite Field. Some coal has been mined in this valley, but its quality is not too good and production was small. Anthracite is dredged from Swatara Creek.

LEHIGH COUNTY

Area 344 square miles. Population 177,395

Lehigh County, according to available figures, stands industrially about fifteenth among the counties in the State. All but the north edge and the southeast corner are in the Kittatinny Valley Area. The southeast part includes a narrow band in the Triassic Area and a zone 4 to 5 miles wide in the Appalachian Mountain Area.

Allentown is the county seat. Railroads and highways offer ready transportation.

Topography. Kittatinny Mountain on the north edge of the county rises boldly from the Kittatinny Valley to 1,600 feet above sea level. That valley is in two parts, on the south a very gently rolling zone at 400 to 500 feet elevation underlain by Cambro-Ordovician limestones, and on the north a rolling hilly country from 600 to 900 feet elevation. The Reading Hills rising from 900 to 1,000 feet enclose irregular limestone valleys down-folded or faulted into the mass of older rocks. The Triassic zone on the south edge is a hilly upland, ranging from 500 to 1,000 feet in elevation.

Rocks. The rocks consist of gneisses, schists, and other igneous and metamorphic rocks, pre-Cambrian age, forming the heart of the Reading Hills, flanked by the Hardyston sandstone of Cambrian age. Stratigraphically above these are the Tomstown (1,000 feet), the Allentown (1,500 feet), the Beekmantown (1,200 feet), and Jacksonburg (700 feet) dolomites and limestones. The Beekmantown contains shaly cement rock. To the north occurs the Upper Ordovician Martinsburg shale or slate, the lower part shale (3,100 feet ±), the upper part sandstone (900 feet ±). The mountains to the north consist of the Tuscarora sandstone about 500 feet thick. The Triassic Brunswick shale, sandstone, and conglomerate on the south edge are estimated to be 1,500 feet thick and are intruded by diabase rocks, surrounding which are zones of baked shale. The rocks are all highly folded except the Triassic, which has a low dip to the northwest.

Mineral resources. The mineral resources consist of brick clays, building stone, cement rock, slate, dolomite, iron ore, limestone, ocher, sand and gravel, and zinc ore. Aside from textiles, cement-rock mining and cement making are the largest single industries in the county. Owing to the complex folding and faulting, the cement rock crops out in irregular banded areas across the center of the county. The amount of rock is almost unlimited. Doubtless, the most attractive mining areas have been exploited already. Limestone and dolomite are quarried also for flux and crushed stone.

Slate comes second among the mineral resources, an industry in which Pennsylvania leads all other States. The slate occurs in two belts: a "hard" slate belt on the south, and a "soft" slate belt on the north. The slate is highly and complexly folded; some of the quarries are several hundred feet deep. The quantity of slate remaining is very large. The output is roofing slate, electrical slate, blackboards, and school slate.

Clays in the county are residual from the weathering of limestone, associated with iron ores, and white clays in the Hardyston formation. The residual clays are abundant and suited for common and face brick and drain tile. The limestones, Hardyston sandstone, and some of the gneisses are well suited for building stone and the limestones and Hardyston have been extensively used.

Lehigh County produces no iron ore today, although it was formerly mined extensively. As many as 261 limonite mines have been worked in the limestone area. Many magnetite mines have been worked in the pre-Cambrian gneissic area. Some of these deposits were worked out, but it is believed that many of them may still contain workable bodies of ore when economic conditions warrant.

Zinc ore occurs near Friedensville and has been extensively mined in the past. Mining difficulties are said to have stopped mining without exhausting the ore. Pyrite has been mined in connection with the iron ore and may be present at depths in some quantity.

Corundum, graphite, and mica are present in the county, but have never been found in commercial quantity. Possibly some of the pegmatites may be found to contain sheets of commercial mica.

Ocher of low grade occurs with limonite and has been produced for many years from "mud-dam" deposits close to the old iron mines. It is used in making paint. Systematic search and careful sampling of the old deposits, especially on the side of the dam farthest from the mine, may uncover material that can be used.

Sand can be obtained from alluvial, glacial, and "mud-dam" deposits, and from decomposed gneiss; and gravel from alluvial and glacial deposits. The sand derived from decayed gneiss is well adapted for a molding or core sand on account of the kaolin, which acts as a binder. It is used also in mortar and concrete. Almost every mud-dam deposit would yield a large quantity of good sand if the material were screened and washed.

LUZERNE COUNTY

Area 891 square miles. Population 441,518

Luzerne County illustrates how a county with great coal resources may not only sustain a large mining industry, but also many other industries depending on coal or taking advantage of surplus "man power" in the miners' homes. In 1938 this county ranked third in employment and wages, and fifth in the value of its production. It contains six cities or boroughs of more than 10,000 population, including Wilkes-Barre, the seventh largest city in the State. Almost two-thirds of the wage earners of the county are employed in the coal mines. Clay products, crushed stone, and sand and gravel are also produced. The population is largely concentrated in the coal basins.

Topography. Aside from the broad, flat, glacial Wyoming Valley, the surface is distinctly hilly, tending to be mountainous ocally. Wyoming Valley has an elevation of about 500 feet. The hills cut in the Middle Devonian and lower Upper Devonian in the Harveyville and Wopwallopen areas are commonly from 1,000 to 1,200 feet above sea level with long slopes to the valleys 100 to 500 feet lower. The "Catskill" hills in the northern and central parts of the county rise between 1,200 and 1,400 feet above sea level and have correspondingly steeper slopes. The Pocono and Pottsville rocks, where level, produce high plateaus 1,800 to 2,000 feet above sea level which enclose shallow basins of Coal Measures; but where these rocks dip steeply around the edge of the Northern Anthracite field, they produce steep-sided mountains 1,600 to 2,300 feet or higher.

Rocks. The rocks consist of about 9,000 feet of pre-Coal Measure rocks and 900 feet of Coal Measures with 16 coal beds. All coal beds total 90 feet; thickest is 37 feet. The Eastern Middle basins contain 558 feet of Coal Measures with 58 feet of coal. The Coal Measures occur in the western end of the Northern Anthracite field and in about a dozen semi-detached basins in the Eastern Middle field. These small basins are connected by the basal Pottsville sandstone. The Northern Anthracite field is rimmed by a double ridge composed of Pottsville and Pocono sandstones separated by the Mauch Chunk red shale. North of the Eastern Middle field, the Mauch Chunk covers a broad area across the county. Its thickness is about 2,000 feet at the south, but it thins to the north. The Pocono group is 600 to 1,000 feet thick, the Catskill 3,400 feet, and the Chemung 2,500 feet.

Mineral resources. As shown in the table of anthracite reserves under the heading of Coal, about one-half of the recoverable coal in the county has been mined, but it has been the coal most readily obtainable; therefore, while there is as much coal yet to be mined it will be harder and more costly to get because it is deeper and thinner. Most of what it left is in the Northern field. It is believed that the Eastern Middle field is rapidly approaching its finish. Modern stripping operations, by taking all the coal classed as unmineable (by underground methods), will lengthen the life of the fields.

Of the other mineral resources, sandstone comes first because of its widespread abundance. The Pottsville sandstone, which rims the coal fields, has supplied some building stone. The Pocono, which makes the second rim, supplies even more. This is the sandstone that makes Nescopeck, Shickshinny, and Huntingdon Mountains and the ridge from Campbells Ledge parallel to the river. Part of the Mauch Chunk is a red quartzite which is being quarried near White Haven and near Wilkes-Barre for curbing and paving. The same rock is used extensively for crushed stone. Sand and gravel deposits are abundant in the Wyoming Valley and in high terraces along the river below that valley. At Berwick and Nescopeck are thick outwash gravels. The difficulty is to find places free from dwellings or other improvements.

The clays under the coal beds are thin or lacking. Likewise, most of the shales accompanying the coals are too slaty or carbonaceous to use in brick making. However, some of them can be used and some of the Mauch Chunk red shale should be of value for brick and tile making. The Devonian shales are abundant and some of them should be suitable for making brick and tile.

LYCOMING COUNTY

Area 1,215 square miles. Population 93,633

Lycoming County, the largest county, lies northeast of the State's center. The north two-thirds is in the Endless Mountains Area, the south third in the Ridge and Valley Area. Most of the county's people and industries are concentrated in the valley of the West Branch of Susquehanna River, largely in the city of Williamsport (value of industrial production $40,620,800 of a total of $44,416,600). The county is very hilly or mountainous. Forests cover 63 percent of the county and farms 42 percent. It is fairly well supplied with railroads and hard roads. At the present time the mining industry of the county is only 1 to 1½ percent of the total value of production, but not for lack of raw materials. The county contains coal, clay, sandstone, limestone, sand and gravel; the last three in abundance.

Topography. The county presents striking contrasts, broad, rolling lowlands from which mountains rise abruptly to 1,300 or 1,600 feet above the adjoining lowlands. Thus, south of Montoursville, the West Branch of the Susquehanna is less than 500 feet above sea level. One and one-third miles to the south, Bald Eagle Mountain reaches 2,120 feet; Elimsport is in sublevel country at 547 feet, flanked by the North and South White Deer Mountains at 1,980 and 1,960 feet. In the northern part of the county, the massive sandstones at the base of the Mississippian and top of the Devonian make the rims of shallow basins rising to 2,000 to 2,300 feet within which some Coal Measures are preserved. The adjoining lands, cut into the softer underlying rocks, are low, but very hilly. Lycoming Creek at Trout Run is only 660 feet above sea level. South of the river, the massive Medina sandstones and quartzites brought up by anticlines form the mountains; but the adjoining strata, mostly thick shale and limestone, have worn down to broad, flat or rolling lowlands.

Rocks. The rocks of this county range from the Allegheny group of the Coal Measures of the northern coal basin to well down to the Cambro-Ordovician limestone in Nippenose Valley. The Ridge and Valley section on a previous page will serve as a reference for this county. In the Ralston-McIntyre basin, the basal Allegheny is thought to be present, and the Pottsville thin. The Mauch Chunk is about 120 feet thick; the Pocono 300 to 500 feet, the Devonian over 9,000 feet, of which the Catskill is 2,500 feet, the Chemung 1,800, Trimmers Rock (Portage) 2,000, the Genesee 1,100, the Tully up to 205, the Hamilton 1,200, the Onondaga to Helderberg, inclusive, 600 feet.

Mineral resources. Coal used to be the county's leading mineral product though exceeded in 1940 by several others. The coal is confined to the centers of the four synclines crossing the county from west to east, but most of it occurs in the northern basin near the north county line, north of English Center and Ralston. These small basins have not been studied in detail, but are thought to carry at least 24 million tons of mineable coal and another 24 million tons of recoverable coal under 2 feet thick to be available in the distant future.

Oil and commercial deposits of gas are believed to be lacking, though small pockets of gas may be found. Sandstone and limestone are both abundant, including the Tuscarora quartzite of the mountains for making silica brick, and limestone for lime, cement, or flux. The high-grade limestone is confined to the Nippenose Valley. The Oriskany sandstone supplies silica sand and some of it may be suitable for glass sand. Sand and gravel are abundant. The black calcareous Trenton limestone or shale has long been mined under the name rottenstone for filler and paint. Clays should be abundant in the Coal Measures in the basins in the north part of the county and shales are abundant in several of the formations. The Clinton "fossil ore" loops around the mountains south of the river and has been mined although only 15 inches thick. Analyses showed from 20 to 30 percent iron. The so-called Mansfield ore carrying fish teeth has been mined locally. It may be 2 to 4 feet thick and carries 32 to 35 percent iron. Ore carrying up to 36 percent iron has been mined from the Mauch Chunk red shale. Besides being low-grade, thin or nodular, some of these ores are high in phosphorus and they do not appear to be of interest at this time.

McKEAN COUNTY

Area 997 square miles. Population 56,673

McKean County on the "north tier", is the third from the Ohio line. It is in the Upper Allegheny oil and gas producing area, but it adjoins the high plateau. The principal mineral resource is oil, but natural gas, clay, and glass sand are produced. Sandstone is abundant and has been quarried and coal has been mined.

Topography. The topography is typically plateau area, consisting of broad, nearly flat summits, 1,900 feet above sea level in the southwest corner to 2,400 feet along the eastern edge, breaking down sharply about 700 feet to the valleys, many of which are fairly flat and open. Indeed, part of Allegheny River valley is gravel filled and flat and more than half a mile wide. Where the streams are close together the upland may be level, but not broad. The low point is 1,240 feet where the Allegheny leaves the county. Prospect Hill, 3 miles east of Smethport, at 2,460 feet is the highest point. Mount Jewett is 2,230 and Kane 2,040 feet above sea level.

Rocks. The Lower Kittanning coal is barely exposed, and 10 to 30 feet below it is the Vanport limestone 4 to 8 feet thick. Below these are five coal beds, clay, shale, and sandstone. The Pottsville underlies the hilltops of most of the county. The Sharon (Olean) conglomerate caps the hills along the New York State line and, where conditions are favorable, makes picturesque "rock cities". Apparently, only the very basal part of the Mississippian remains. The Knapp formation, 70 to 213 feet thick, is believed to be the age equivalent of the Berea farther west. It is composed of two sandstones or conglomerates separated by 40 feet or less of shale. The Devonian rocks include at the top, the Oswayo formation 200 feet thick, gray to greenish-gray sandstones; the Cattaraugus formation 300 to 345 feet thick, streaked with red strata, representing the westward thinning out of the Catskill red beds; the Conneaut group, including at its base the Cuba sandstone or Bradford First sand, 650 feet thick; the Canadaway group (formerly called Chemung) with the Bradford and other sands. In the Bradford district, these sands are as follows:

Interval above and below the Bradford Third sand in the Bradford District. (Fettke)

	Feet
Bottom of Cattaraugus red beds	1255
Top of sands	
Bradford First	610
Sugar Run	525
Chipmunk	440
Bradford Second	325
Harrisburg Run	230
Bradford Third	0
Lewis Run	100
Kane	240
Haskell	450
Tully limestone, 4 to 18 ft.	2450
Onondaga limestone, 48 to 70 ft.	2900
Oriskany, 0 to 20 ft.	2950
Medina (white) group, 140 ft.	4450

Mineral Resources. Oil. Oil is and has been the leading mineral resource. McKean County oil reserves are discussed in the oil and gas section. Present estimates are that 65 million barrels remain to be recovered by present methods. As an estimated 875 million barrels of oil are still in the rocks, it is hoped that methods for recovering a much larger percentage of the oil will be devised before the 65 million barrels are gone. High cost and low prices are likely to prevent much greater recovery at the present time. It remains, however, a challenge to the petroleum engineers. Naturally, oil refining is a large industry in the county.

Gas. The county has for many years produced from 2 to 5 billion cubic feet of natural gas annually and will doubtless continue to produce gas for some time. Gas wells in the Bradford Third sand have yielded up to an estimated 24 million cubic feet a day, but that is rare.

Clay and shales. Shales are and have been used for making brick and tile, and suitable shale should be abundant at many horizons. Clays 2 to 3 feet thick occur below the Lower Kittanning and Clarion coals. A clay at Clermont 4 to 19 feet thick was long mined by shaft. Clays up to 12 feet thick have been mined on the Mercer (Alton) and Sharon (Marshburg) horizons. On the whole, the county seems to be well supplied with clay and shale suitable for conduits, refractory brick, face brick and tile, and terra cotta.

Coal. The coals include the Lower Kittanning, Clermont, and Alton beds. The Lower Kittanning (Dagus) coal 3 feet thick occurs only in the southern hilltops. In most of the county, except the northeast corner, occur the "Clermont" or Clarion coal, 3 feet thick; the three Alton coal beds, the Upper 2 to 3½ feet, the Middle 4 to 8 feet, the Lower 4 feet, which were formerly mined at Alton, Clermont, and elsewhere; and the thin Marshburg (Sharon) coal 170 feet below the Vanport limestone.

Sandstone. Sandstone is abundant in the county. Most of that used has come from large talus blocks, mostly from the Pottsville sandstone. Flagstone from the Catskill has been quarried and shipped out of the State. On the whole, sandstone is abundant and well suited to general building purposes. Like most other stone, it needs periodical cleaning. Sand and gravel are not listed in the county's industries, but doubtless occur in abundance in the stream bottoms.

MERCER COUNTY

Area 681 square miles. Population 101,039

Mercer County is on the west line of the State, the third south of Lake Erie. It lies entirely in the Upper Allegheny Area. The county is on the north edge of the coal field and coal is limited to the southeast half of the county. Most of the surface is underlain by Pottsville sandstone, except the broad valleys in the middle and basal Pocono in the northwest corner. The coals, clays, and limestones are, therefore, limited. Sandstone is abundant. Iron ore occurs at the lower Mercer and some other horizons. Glacial deposits cover the whole area. Most of the oil and gas sands of the fields farther east are lacking under this county. The Berea sand is present and carries both oil and gas; 3,200 feet lower is the Oriskany sand and 1,500 feet still lower is the Medina sandstone with rock salt in quantity half way between.

Topography. The county as a whole is sublevel with broad uplands sloping gently 100 to 200 feet to equally broad valleys. There are many areas of swamp land, some in the valley bottoms, some on the uplands. The uplands range from 1,200 feet above sea level along the west border to 1,500 feet along the east border. A few small hills rise abruptly above the generally level upland. Bluffs along the main streams in places are more than 100 feet high.

Rocks. The rocks include the lower part of the Allegheny group in the hilltops in the southeast corner of the county with the Middle and Lower Kitanning coal and clay, Vanport limestone, and Clarion and Pardoe ("Brookville") coals. Most of the county is underlain by Pottsville rocks. The Homewood sandstone member is 50 feet thick; the Mercer member about 50 feet, including the Upper and Lower Mercer limestones, coals, and iron ores. The Connoquenessing member has an upper and lower sandstone and intermediate Quakertown coal, shale, and iron ore. The Sharon member 50 to 60 feet thick consists of shale, the Sharon coal and clay, and the Sharon conglomerate 20 feet thick. The whole Pottsville is about 300 feet thick. The horizon shown on the Second Survey map as "outcrop of interval between the Sharon conglomerate and Shenango sandstone" is now thought to be at the Patton red shale horizon at the base of the Burgoon sandstone. The latter is lacking. The Mississippian in this county consists of three Shenango sandstones within 150 feet; the Cuyahoga 150 feet, and the Berea sandstone 60 feet thick, including the Corry. Over all the rocks is the glacial drift, of clay, sand and gravel, which varies from 25 feet or less on the upland to fills 200 feet deep in preglacial channels. In preglacial time all these channels drained northwest toward Lake Erie. In some instances the ground sloped toward the ice. Lakes resulted that ultimately disappeared, leaving only lake deposits. Rocks of Mercer County dip south 12 to 15 feet to the mile.

Mineral resources. Coal is probably the most valuable mineral resource in the county though water contained in deep gravel-filled channels is a permanent resource and in the end may exceed the value of the coal. Most of the coal is in the southeast half of the county. The Lower and Middle Kittanning coals occur only in hilltops in Liberty and Pine Townships. They are 2 and 3 feet thick and of small area. The Clarion coal is thin and the Pardoe ("Brookville") coal 4 to 5 feet thick is mined by shafts and stripping around Pardoe and Grove City. This county is one of a few having Sharon coal, which differs from the higher beds in being a block, non-caking coal which could be used in the furnaces without coking. This coal appears to have been laid down in small basins or old stream channels and has a maximum thickness of 4 feet. Probably none of it remains at the present time. The county may contain 25 million tons of coal over 3 feet thick, and possibly 100 million tons of coal 2 to 3 feet thick, now available; and 165 million tons of coal under 2 feet thick, recoverable some time in the distant future.

An estimated 6,000 acres of the county are, or have been, underlain with oil-bearing rocks. It is estimated that 36 million barrels of oil were in the ground originally, of which 4 million barrels are still obtainable, including all secondary oil that can be gotten under present conditions; or 15 million barrels if the prices were high enough. The oil comes mainly from the

Berea sandstone. To the present only salt water has been encountered in the Oriskany sand. Drilling in this county to the Medina has found it dry. That does not mean that there is no gas in those sands, but is not encouraging.

The Vanport limestone is confined to the southeast part of the county. The full thickness is 12 to 15 feet. The upper part as usual is light-gray and pure. The lower 3 or 4 feet is a mottled dark-blue and not so pure. Of the two Mercer limestones, the lower appears to be the more persistent, but is sometimes replaced by iron ore. The Mercer limestones are usually reported as less than 3 feet thick.

The Homewood sandstone from 30 to 70 feet thick appears to be more persistent in Mercer County than in the counties to the south. It ranges from white to gray and from fine-grained to pebbly. In parts of the county it is a good building stone. The Upper Connoquenessing sandstone is a massive cliff-maker, though locally it appears to be replaced by shales. The Lower Connoquenessing sandstone has a maximum thickness of 50 feet and locally is replaced by shale. In places it makes a good building stone. The Sharon sandstone, 20 feet thick, is in two layers, the upper moderately coarse, white, and an excellent building stone; the lower a loosely cemented mass of pebbles. Locally, as at Greenville, it makes excellent flags.

Iron ore in beds or nodules occurs at several horizons. Although used extensively nearly 100 years ago, none of these ore beds has value at this time. They may be mined at some future time.

Silica sand produced by crushing and washing high-silica beds of the Pottsville sandstone is sold for building, glass, traction, and fire sand.

Bank sand and gravel for building purposes is widely available throughout the county.

MIFFLIN COUNTY

Area 431 square miles. Population 42,993

Mifflin is a long, narrow county in the central part of the State, traversed for half its length by Juniata River. The county is in the center of the Ridge and Valley Area, with its axis running northeast-southwest in conformity with the mountain ridges. Jacks Mountain is 30 miles long and cut by only one gap within the county at Reedsville. The gap at Mount Union is on the Huntingdon-Mifflin county line. Lewistown is the county seat and largest borough.

Most of the highways follow the principal parallel valleys. Only Route 322 crosses the mountains. A railroad follows the Juniata River and Jacks Creek the full length of the county, and a branch connects Lewisburg and Milroy.

The geologic section extends from Lower Ordovician limestones to Upper Devonian shales and sandstones, and includes the Tuscarora quartzite, Clinton iron ores, Helderberg limestone, and Oriskany sandstone. The mineral resources from these rocks are limestone, glass sand, silica sand, crushed stone, ganister, brick shale, and iron ore.

Limestone. Limestone of various character is abundant throughout the county. The greatest area of limestone is in Kishacoquillas Valley, extending about 25 miles from Allensville to Siglersville, and 3 to 4 miles wide. The limestones are of Cambro-Ordivician age. Many of them seem to be fairly high in silica and magnesia but search might reveal the presence of low-silica and even low-magnesia stone. Small openings have been made on many of the farms for agricultural lime, and some limestone has been used for building. Large quarries near Naginey produce crushed stone and fluxing stone.

The Helderberg and Tonoloway limestones crop out in two narrow zigzag belts in the eastern part of the county. The stone has been quarried principally for crushed stone for concrete and road construction, and for furnace flux; it has been used also for building and burned for agricultural lime. Many openings have been made near Lewistown and along the Juniata Valley. Some of the stone averages 96 percent calcium carbonate but in some places it is high in silica.

Glass sand. The Oriskany sandstone crops out in two main belts nearly the whole length of the county on the east side of Jacks Mountain and paralleling the Helderberg limestone. It is highly siliceous and locally friable and is quarried for glass sand, building sand, and silica sand for steel molding. As the length of the outcrops is more than 50 miles, doubtless high-grade material could be produced from other localities than those already opened.

Ganister. The Tuscarora formation crops out in Jacks Mountain across the middle of the county and in Stone, Long, and other mountains on the Centre-Huntingdon county boundary, and in Blue and Shade Mountains on the south boundary. In places the floe is 97 percent silica and 30 to 75 percent of it might be usable for silica brick. The only production of ganister in 1943 is on Blue Mountain in the Narrows east of Lewistown, where the floes are very large and, in places, thick. Should the demand for silica brick require it, ganister could be stripped from floes elsewhere on the mountains, but at no other place is the material so close to a railroad.

Sandstone. The hard sandstones in the mountains and lesser ridges are suitable for the common needs in building and are so abundant throughout the county that one may assume a nearby source for the stone in the older buildings, mountain sandstone being used for all stone foundations or buildings in or close to the ridges, and limestone in the broad valley from Allensville to Milroy. Ample supplies are available but have been little used.

Brick shale. The railroad northeast and southwest from Lewistown follows the Clinton shales, which probably could be used for making building brick and hollow tile. Clays resulting from the weathering of the limestones seem of little importance. Building brick are not made in the county.

Sand and gravel. Doubtless there are deposits of sand and gravel on the broad flats along Juniata River but not much use is made of this material.

Iron ore. The limestone floor of Kishacoquillis Valley contains deposits of brown hematite iron ore once extensively mined on the surface. The ore mined nearly a century ago near Belleville was pipe ore. In the Lewistown Valley, 38 miles long and 6 miles wide, the Clinton and Marcellus formations carry iron ore and perhaps several hundred thousand tons were mined prior to 1890 and melted in local furnaces. The ore was mined by drifts, or stripped along the outcrop where the beds stand at a high angle, or it was recovered by stripping where the dip was low and the cover not too heavy. The Sand Vein in places was 16 inches to 2 feet thick and siliceous. In one place three Danville ore beds occur within 15 feet of strata, the thickest ore bed being 12 to 15 inches, carrying 26 percent iron and 47 percent calcium carbonate. In another place a Danville bed 16 to 18 inches thick had 12 inches of fossil ore carrying 46.9 percent iron.

Doubtless there are large quantities of iron ore in the county, but whether the quality of the ore and thinness of the beds will permit profitable mining remains to be proved. It is possible that spots may be found where a fair grade of nearly flat-lying ore close to the surface might justify an attempt at mining.

MONROE COUNTY

Area 611 square miles. Population 29,802

Monroe County borders the State of New Jersey. Delaware Water Gap and Pocono Mountains are well-known features. Tannersville, Mountain Home, Buck Hill Falls, and Tobyhanna are familiar names to those who vacation in this region.

The two Stroudsburgs have 12,590 people or 40 percent of the population. Two railroads from the Northern Anthracite field cross the county and converge at Delaware Water Gap. The county has 365 miles of improved State highways.

The western part of the county is a high plateau known as the Pocono Mountains. Its surface is 1,800 to 2,100 feet above sea level, and towers about 1,000 feet above the country to the east. This low country sloping away from the bold escarpment is a series of long, high ridges separated by narrow valleys. The highest ridge, Kittatinny Mountain, forms the southern boundary of the county.

Most of Monroe County was covered by the last advance of glacial ice; glacial drift is common except in four southern townships. The rock formations exposed in the county range in age from the Mount Pleasant formation of the Catskill continental group down to the base of the Tuscarora sandstone. Upper members of the Catskill group underlie the plateau, lower members make the escarpment and foothills. The Oriskany sandstone makes a ridge across the southern part of the county, which is separated by a belt of Clinton shale and Helderberg limestone from the Tuscarora rocks in Kittatinny Mountain.

The structure of the northern part of Monroe County is similar to that of Pike County, with gently dipping or horizontal beds on the Pocono Plateau. The dip increases rapidly southeast of the escarpment. Southern Monroe County is traversed by a series of folds with dips up to 40°.

The mineral resources of Monroe County are nonmetallic. Occupancy for more than 250 years has failed to disclose ores of metals except iron; search for them would be fruitless. Nodules of siliceous brown hematite, small deposits of bog iron ore, and of ochre were reported more than 60 years ago. It is questioned if these minerals occur in commercial quantity. Coal, oil, and natural gas are lacking. The resources are limestone, sandstone, clay, shale, sand, and gravel.

Limestone. Practically all the limestones of Monroe County are confined to the extreme southeast border where two more or less parallel bands cross the Delaware River near Bushkill, pass southwestward through Stroudsburg to the county line beyond Kunkletown. These bands are the Onondaga and the Helderberg limestones. In former years they were quarried and burned for agricultural lime; in recent years the output has been crushed stone for highways, concrete structures, and riprap. The beds differ in thickness and quality; some are high in lime, some low. By careful search, stone suitable for selected purposes can be found in quantity. Much of the outcrop is covered by glacial drift and by wash from the adjacent ridge but the deposits are believed to be continuous even though hidden.

Sandstone. Sandstone is abundant on the plateau and in the ridges in the southeast part of the county. It has been little used for building stone, perhaps because glacial boulders are more readily available. There is no question, however, that sandstone suitable for building stone can be found in quantity within a few miles of any building site in the county. Red may be the prevailing color on the plateau, greenish and gray stone in the lower country.

Flagstones can be raised from various horizons in the Catskill beds, as they once were on Marshall Creek and Brodhead Creek.

A large quarry in hard sandstone at Analomink has been operated for railroad ballast.

Shale. Soft shales and possibly glacial clays on the Pocono Plateau could be used for making brick, as could some shales in the Chemung and Portage formations in the foothills. These materials are in broad belts but brick have not been in great demand because so much of the county is high and wild, dotted with lakes and ponds, and devoted to recreation rather than permanent residence.

Clay. Excellent white clay occurs in the ridges made by the Oriskany formation and has been mined extensively in the Saylorsburg-Kunkletown region. Its principal use is to whiten portland cement. How much good clay still remains along the ridge is uncertain.

Sand and gravel. Glacial drift deposits of variable thickness cover most of the county north of the Wisconsin drift border and a good part of the county south of that border, which traverses the northern part of Tunkhannock Township, swings around Pocono Knob, passes through McMichael, Brodheadsville, and Saylorsburg, and crosses Kittatinny Mountain at Fox Gap.

A large part of the drift is sand and gravel; lesser parts are clay and boulders. Besides being spread over the surface it fills several buried valleys. The largest of these begins near Bushkill, extends through Stroudsburg to Sciota, where it bifurcates. Cherry Creek flows over another buried valley. Much of the filling of these valleys is stratified fine sand known as quicksand. Huge mounds of drift are scattered along the buried valleys. The supply of sand and gravel for common purposes, therefore, is abundant and widely distributed.

MONTGOMERY COUNTY

Area 484 square miles. Population 289,247

Montgomery County lies along the Schuylkill and is bounded by Berks, Bucks, Chester, Delaware, and Philadelphia Counties. Norristown is the county seat and largest municipality. Pottstown is the second largest borough. Railroad transportation is furnished by the Pennsylvania and the Reading. Important highways traverse the county, which has 755 miles of improved State roads.

The county is largely underlain by sandstone and shale of Triassic age, which make red soil. Trap rock is abundant in the western end. Close to the border of Philadelphia County is a belt of pre-Cambrian gneisses, Cambrian quartzite, and Ordovician limestone. The mineral resources are limestone, dolomite, marble, quartzite, building stone, clay, shale, sand and gravel.

Limestone and dolomite. Naturally the first quarrying of limestone and dolomite was for building stone and to burn for agricultural lime. This was followed by their use as flux in local iron furnaces. Present production is for high-grade lime for chemical industries, portland cement, magnesia, flux, and crushed stone for concrete aggregate and road metal.

These rocks underlie Whitemarsh and Chester Valleys and range from less than 1 percent silica and more than 40 percent magnesium carbonate to upwards of 90 percent calcium carbonate.

A series of dolomites aggregating several hundred feet in thickness lies next to the Chickies quartzite. Overlying the dolomite and in general occupying the central part of Whitemarsh and Chester Valleys there is a thick band of interbedded dolomite and limestone that seems to be of Beekmantown age. This is overlain by a more or less persistent band of coarsely crystalline gray marble. The youngest limestone formation occupies the southern part of the two valleys and is a micaceous limestone with lenses of marble, dolomite, and mica schist.

Dolomite is quarried at Plymouth Meeting and Port Kennedy for the manufacture of magnesia; in Plymouth and Upper Merion Townships for crushed stone; at West Conshohocken for portland cement; at Bridgeport for lime and flux; and at Plymouth Meeting and North Hills for lime. The deposits are extensive.

Marble. A band of marble is rather persistent in the southern part of the county. It ranges from clear white to gray to mottled, and some is pink. The two places formerly worked extensively are Marble Hall and southeast of King of Prussia. Quarries were operated in the 19th century for building stone, door and window sills, and steps, largely for construction in Philadelphia. Since about 1930 marble has been mined 200 to 300 feet underground at Shainline, a mile southwest of Bridgeport, and pulverized for filler in paint, putty, rubber, caulking compounds, and other products.

Quarrying at Marble Hall began about the time of the Revolutionary War and continued until long after the Civil War. Other quarries might be opened were it not that the deposits occur under golf courses or private estates.

Quartzite. The Chickies quartzite, also called Edge Hill stone, crops out in a hairpin loop from Hickorytown through Whitemarsh to Willow Grove and back through Edge Hill to the Schuylkill at Spring Mill. Another outcrop extends from Huntingdon Valley to the east corner of the county.

This formation is in part quartz-sericite schist. It has been quarried in several places, particularly near Edge Hill, and the bulk of the material has been used for lining furnaces in steel mills. The quartzite or ganister near Plymouth Meeting is quarried and made into refractory brick. Both the quartzite and the sericite schist break naturally in slabs with square joint faces, and are used for building stone.

Building stone. Besides the limestone, dolomite, marble, and quartzite already mentioned, several other varieties of stone are used for building. Reddish, greenish, and brown sandstones of Triassic age have been quarried in several parts of the county, and black sandstone near intrusive diabase. Trap rock or diabase has been used around Schwenksville.

Baltimore gneiss is the bedrock in a large area extending from the eastern corner of the county to Glenside and beyond, and from Bethayres north to Byberry. It furnished much stone for the cathedral at Bryn Athyn and is worthy of further development.

The Wissahickon gneiss underlies a considerable area in the southeastern part of the county. The largest group of quarries in this rock is along Rock Hill Road near West Manayunk. Quarries at other localities, especially one at Hill Crest, 2 miles west of Jenkintown, have been worked at various times for rough and dressed building stone, including mica schist as well as gneiss.

Crushed stone. Stone crushed for concrete aggregate, road metal, etc., includes limestone and dolomite at several quarries within a few miles of Norristown, baked Triassic sediment at Green Lane, Perkiomenville, and Sanatoga (mixed with trap rock), quartzite near Edge Hill, and gneiss at Bethayres.

Clay and shale. Soft red Triassic shales are abundant in the northern half of the county and brickyards are located at Fairview Village, Lansdale, and Norristown. These shales are suitable for making common and face brick and drain tile, and are used at Pottstown for various kinds of vitrified clay products.

Surface clay is used at North Wales for making pottery and at Roslyn for common brick. Plastic yellow clay residual from limestone occurring in small pockets may have some ceramic uses.

Outliers of highly colored plastic Cretaceous clays up to 40 feet thick occur and were formerly used near Spring Mill and Harmansville for making fire brick, furnace lining, terra cotta, and pottery.

Sand and gravel. Probably any usable sand and gravel is in terrace deposits along the Schuylkill or derived from deeply weathered Triassic conglomerate. This material has been dug near Norristown and Royersford.

Iron ore. In Upper Merion Township brown hematite or limonite occurred in large quantity and was mined extensively in the 1870-80's. The deposits extended from the Schuylkill beyond Henderson Station. The ore was in clay residual from limestone.

Iron ore occurring in clay was mined extensively in Sprinfield Township, and was found in Plymouth and Whitemarsh Townships. It is questioned whether any commercial deposits remain.

MONTOUR COUNTY

Area 130 square miles. Population 15,466

Montour, the smallest county, lies between the forks of the Susquehanna above Sunbury. U. S. and State highways cross the county and railroads traverse the central and southern parts. Danville, the county seat and largest borough, is on the Susquehanna.

The rock strata range from Clinton beds of Silurian age to Catskill beds of Upper Devonian age and include Clinton iron ores, Helderberg limestone, and Oriskany sandstone.

Iron ore. In the vicinity of Danville large quantities of iron ore were mined many decades ago for local furnaces. Nearly 100 years ago (1846) H. D. Rogers, State Geologist, estimated the good ore in the ground in two beds on the two sides of Montour Ridge along one mile of outcrop and above water level amounted to 700,000 tons. (2d Survey, G 7, p. 388.)

One bed is 14 to 18 inches of fossiliferous iron ore; at Danville it is 16 inches thick. At the surface it is a mud-like deposit but changes with depth to a compact limy rock filled with fossils and is known as hard or block ore.

The other bed is a ferruginous band in the Iron sandstone. It is hard, siliceous, and 14 to 16 inches thick, and, like the fossiliferous ore, was mined extensively north of Danville.

East from Danville iron ore was mined a century ago in Cooper Township, but on the west, in Liberty Township, it is concealed by float, if present, and has not been mined.

Large tonnages of iron ore may be present in Montour Ridge across the southern part of the county. Possible commercial development must consider that the beds are thin, dip 30° to 35°, and may be very low grade or lacking.

Limestone. The Helderberg limestone crosses the southern townships in two east-west belts, and zigzags across Limestone Township, with projections into Derry. It has been quarried in these two and in Liberty, Valley, and Cooper Townships for various purposes, including crushed stone, building stone, flux, and lime. Old quarries and lime kilns are most numerous in the vicinity of Washingtonville.

Limestone is now quarried at Grovania and one mile southeast of Limestoneville for crushed stone. As in adjoining counties, the Helderberg contains some high grade, low magnesian limestone suitable for lime or flux. It is interbedded with siliceous and argillaceous limestones of much less value. Some beds are fairly high in magnesia.

About 25 miles of outcrop assures an abundance of stone for years to come.

Silica sand. The Oriskany formation in Montour County is composed largely of black impure chert and "rotten, dirty yellow beds containing some lime." This description suggests that it is not a choice source of silica sand.

Building stone. A quarry one mile east of the State Hospital at Danville in a dark bluestone of Hamilton age has furnished much square-faced building stone. Sandstones in the Chemung formation are suitable, as are the Helderberg limestones.

Molding sand. Deposits of sand on the terrace 50 feet or more above Susquehanna River and probably of glacial origin are dug near Danville for casting light ornamental iron, small hardware, and brass. A deposit probably of fluvial origin along the river 3 miles west of Catawissa has furnished several grades of bonded molding sand.

Brick shale. Although there is an abundance of shale that should be excellent for making brick there are no brickyards in the county. The best shales would no doubt be those in the two lowlands underlain by the Bloomsburg red shales.

NORTHAMPTON COUNTY

Area 372 square miles. Population 168,959

Northampton County is small in area, but large industrially, including Easton on the Delaware River, Bethlehem on the Lehigh River with its great Bethlehem Steel Company plant, and the heart of the Lehigh Valley cement and slate districts. Most of the county lies in the Kittatinny Valley Area. Bethlehem with 58,490 people and Easton with 33,589 are the only cities.

Topography. Kittatinny Mountain on the north boundary of the county rises to 1,600 feet above sea level and is even-crested. South Mountain back of Lehigh University culminates at 994 feet and the hills between Saucon Valley and the Delaware culminate at 700 to 1,000 feet. The lowest point is on the Delaware River where it leaves the county, altitude 150 feet. The Saucon Valley and some smaller valleys among these hills are inliers of limestone dropped down by folding or faulting. The rest of the county is in the Kittatinny Valley. The south half of that valley is underlain by limestone and is gently rolling, with hilltops averaging about 420 feet above sea level. The north half is underlain by sandstone and shale or slate and is hilly, ranging in altitude from 500 feet to almost 1,000 feet.

Rocks. The oldest rocks are igneous and metamorphic, consisting of granites, gneisses, schists, pegmatites, and graphite-bearing limestones of pre-Cambrian age. They are confined to the area south of Lehigh River and two small localities: Chestnut Ridge north of Easton and at Camels Hump and near-by. Flanking these in many places is the Hardyston sandstone or quartzite of Lower Cambrian age up to 200 feet thick. It is overlain by a great thickness of dolomites and limestones of Cambro-Ordovician age, the Tomstown 900 to 1,000 feet, Allentown 1,500 to 1,600 feet, Beekmantown 1,000 to 1,200 feet, and Jacksonburg 700 feet thick. Above these and of Upper Ordovician age is the Martinsburg shale several thousand feet thick and its sandstone member. Kittatinny Mountain up to its crest consists of the Shawangunk conglomerate and sandstone of Lower Silurian age, equivalent to the Tuscarora and Clinton to the west. About 300 feet of Brunswick shale of Triassic age occurs in the south corner of the county. The rocks are all intensively folded and faulted. In general, however, they crop out in zones crossing the county from north of east to south of west. Small parts of the county are covered with glacial deposits.

Mineral resources. The mineral resources of the county are limestone, slate, building stone, clay and shale, serpentine and talc, sand and gravel, mineral pigments, and iron ore.

Limestone is the greatest mineral resource. The shaly Jacksonburg limestone, the basis of the cement industry, crosses the county in a narrow belt. The composition of the limestone varies from place to place, but the future supplies for portland cement are very large. The present quarries and 13 plants occupy only a small fraction of the outcrop.

The Tomstown, Allentown, and Beekmantown formations make a broad belt of limestone and dolomite across the county that can supply the demand for agricultural and building lime, flux, and crushed stone indefinitely.

Slate occurs in two belts. The "hard" slate belt through Belfast and Chapman Quarries furnishes mostly roofing slate; the "soft" slate belt from Bangor to Danielsville yields roofing slate and mill stock, which includes rough or finished slate for structural purposes, toilet stalls, grave vaults, billiard table tops, electrical switchboards, and blackboards. The deposits are very extensive. One quarry is more than 700 feet deep. Twenty companies produce slate in this county when demand justifies. A stone in the slate beds but nearly lacking in slaty cleavage is abundant in the Martinsburg formation near Kittatinny Mountain and suitable for an abrasive. A small quantity of it has been used for razor hones.

Building stone produced in recent years has been largely the Hardyston sandstone and quartzite, which is widely distributed south of Lehigh River. Gneisses in the same region range from dark to light, uniform to banded, and could furnish an unlimited supply of building blocks and crushed stone. Limestone blocks will long be used in small amounts for construction, but the production is restricted to well-shaped blocks shot down in blasting the stone for other uses. Waste blocks of slate from the huge piles at the quarries would make slabby building stone, and glacial boulders and river cobbles are also a source of building material.

Clay and shale for structural and ceramic products are abundant. Soft shale and slate, residual clay from the disintegration of limestone, glacial clays, and recent alluvium occur in the county and can be used for making common and face brick, drain tile, stoneware, and flower pots. Brickyards are at South Easton, Bingen, and Georgetown.

Serpentine and talc in Chestnut Hill north of Easton are crushed for terrazzo, and pulverized for mineral filler in paper, paint, and rubber. The serpentine could be used for interior decoration if slabs of suitable size can be found.

Sand and gravel are obtained from terrace and kame deposits near the Delaware River. The principal production is near Mt. Bethel. An unusual sand is obtained by screening decomposed gneiss near Bethlehem and Hellertown. It is used by furnaces and foundries for molding or core sand.

Mineral pigments that have been produced in the county are ocher, umber, and black shale. The ocher is associated with iron ore and washed ocher of fair quality occurs in some of the mud dam deposits at the old iron ore pits. Umber derived from the decomposition of the Hardyston quartzite occurs at Camels Hump. These deposits have been utilized for paint but the demand is small. Very black carbonaceous shale near Nazareth was used for many years for making black paint.

Iron ore occurs as limonite and siderite. For nearly 100 years the mining of iron ore was an extensive industry. At least 84 limonite mines have been worked in the county, but mining ceased several years ago. The present great iron and steel industry in the county began when the iron mines were in active operation. Although the ore in some mines was practically exhausted, it is believed that considerable iron ore remains underground and may be mined when other sources are exhausted.

NORTHUMBERLAND COUNTY

Area 454 square miles. Population 125,887

Northumberland County is on the east side of Susquehanna River at its forks. Sunbury is the county seat. Federal and State highways reach all parts. Railroads follow the rivers and cross the south end through the coal field.

Rocks exposed extend from the Clinton shales to the Coal Measures. The principal mineral resources are anthracite and crushed stone.

Anthracite. Northumberland County stands third among the counties in its original content and present reserves of anthracite. It includes the western half of the Western Middle field with nearly 2 billion tons of coal left, of which over 1 billion tons are classed as recoverable. The coal is in a major basin, which folding divides into at least six minor basins. Some of these basins are very deep. Thus, in the Mt. Carmel basin the Mammoth bed descends to 700 feet below sea level or 1,500 feet below the surface, and the Lower Lykens Valley bed descends to 1,500 feet below sea level or 2,300 feet below the surface. The coal beds are thinner than in some of the other fields, and many of them split up. Thus, the Lykens Valley is in three splits which average 3 feet 1 inch, 4 feet 9 inches, and 4 feet; the Buck Mountain in three splits with 7 feet, 7 feet 9 inches, and 4 feet 11 inches of coal; the Mammoth in four splits with 4 feet 3 inches, 8 feet 6 inches, 8 feet 3 inches, and 13 feet 1 inch of coal. The other beds or splits range from 3 feet 11 inches to 6 feet 4 inches of coal, not including partings. The depth of the coal and the large quantity of water to be pumped will retard mining some of these beds until the more cheaply mined beds here and elsewhere have been mined out.

Limestone. This county is well provided with limestone as the Helderberg loops back and forth in narrow bands in all five townships above the Susquehanna and occurs in three areas south of Sunbury. The chief quarries in the county are in the vicinity of Turbotville, Milton, and Dalmatia. These quarries have been in operation during recent years. Their output is crushed stone, largely for road metal, and lime.

In the 19th century it was customary for farmers to quarry limestone and burn it for agricultural lime. This was done in Lewis, Delaware, Turbut, Chilisquaque, Point, Upper and Lower Augusta, Jordan, and Lower Mahanoy Townships, but most of the quarries have long been abandoned. Limestone also was sold to iron furnaces for flux.

The Helderberg limestone ranges from massive, hard, blue beds of high-calcium stone to impure shaly beds. As there are many miles of outcrop and the Helderberg group is 300 feet thick, there is opportunity for extensive quarrying.

Limestones other than those of the Helderberg group have little, if any, economic value, and so far as known have not been quarried.

Sandstone. The Oriskany sandstone in the northern part of the county is cherty and limy, but along the river in the southern part it is much less cherty and more massive. Massive sandstones in other formations make ridges and are locally almost a quartzite. Some of these could be used for building or as crushed stone for road metal.

Shale. Shales in the Clinton and Hamilton formations suitable for making brick and tile are readily available along Susquehanna River. Clinton shales at Watsontown are used for making common and red face brick, vitrified acid brick, paving block, and formerly made clinker that was crushed for roofing granules, tennis courts, and driveways. Some of the soft Mauch Chunk shales surrounding the anthracite field in the south end of the county may be suitable for making brick.

Sand and gravel. Deposits of sand and gravel occur in the flood plain and terraces of the Susquehanna and on some of the tributaries. Possibly large deposits in the upper end of the county may be of value. Molding sand used for making medium-weight to light iron castings is dug at Riverside (South Danville). Several fields have been stripped in half a century, but the deposit is extensive.

PERRY COUNTY

Area 550 square miles. Population 23,213

Perry County is in the south-central part of the State, west of the Susquehanna River, and bounded on the south by Kittatinny Mountain. The county is in the Ridge and Valley Area. Juniata River crosses the eastern part. New Bloomfield is the county seat. It is well served with transportation facilities; the main line of the Pennsylvania Railroad follows the Juniata River, and hard-surfaced roads traverse the valleys.

Rocks. The exposed rocks range from Ordovician shale and limestone in the northwest corner of the county to Mauch Chunk (Mississippian) shale at the east end. The Tuscarora sandstone of Silurian age makes the boundary mountains, Devonian sandstones form lesser ridges, and the Pocono sandstone makes Cove Mountain on the Susquehanna. Large areas of the hilly interior are underlain by Silurian and Devonian sandstones and shales. The rocks are closely and intricately folded, and several major faults interrupt their continuity.

MINERAL RESOURCES

The mineral resources are iron ore, limestone, sandstone, clay, and shale.

Iron ores. From about the middle to near the end of the 19th century, mining and smelting of iron ore was an important industry in Perry County. Much of the ore was smelted locally but where transportation facilities were available, it was shipped to furnaces elsewhere. The ores are hematite and limonite with minor amounts of specular hematite. Mineable ore occurs at three horizons, which are, in order of importance: Clinton fossil iron ore, Marcellus brown hematite, and Hamilton (Montebello) fossil iron ore. Thinner ores also occur in the Oriskany, Portage-Chemung, Catskill, and Pocono formations. The mineable ores are generally thin, averaging about one foot thick, and are non-persistent. They have relatively little economic value now, but constitute a future source of supply. The outcrops of the iron-bearing horizons may be easily traced by their association with beds that are prominent features of the geology. There is a general tendency for a bed to thicken at the apex of a fold, therefore, should prospecting be contemplated, it would be well to determine the geologic structure at the outset.

The Clinton fossil iron ore is hematite. It is the most important deposit in Perry County and occurs in the rocks of the middle Silurian age, which crop out in the northern, western, and southern parts of the county. The ore is present in one or more beds and commonly lies directly on sandstone. In the latter part of the 19th century, this ore was mined rather extensively north of Millerstown, where it is from 12 to 18 inches thick. Many thousands of tons were shipped, most of it to Harrisburg and Reading. Other deposits of this ore have been proved at various localities in the county, particularly in Kennedys Valley, Buck Hills, and Conococheague Mountain.

The Marcellus brown ore was reported as a concretionary limonite which lies at the base of the Marcellus shale and is usually underlain by limestone. Its outcrop can be followed with respect to the Oriskany sandstone. White and dark clays immediately associated with the ore necessitate washing. The ore is present in one or more beds, and the ore and clay have a maximum thickness of 20 feet. Where the underlying limestone is absent, the ore tends to thicken and is in contact with the Oriskany sandstone. The Marcellus ore has been mined at various places in the county, notably at the Clouser works near Newport, the Reeder works near New Bloomfield, near Little Germany, and Landisburg.

The Hamilton (Montebello) fossil ore lies on top of the Hamilton sandstone. It is usually two feet thick, but contains considerable impurities. It is erratic in occurrence, being missing in sizable areas, particularly in the northwestern part of the county. The ore was mined at Manorville, Old Perry Furnace, Old Juniata Furnace, near Newport, and other places. Much of the ore was used at the Duncannon Furnace for mixture with other ores.

Limestone. Most of the limestones in Perry County are contained in the Helderberg group, which within itself is predominantly composed of limestone having a total thickness of over 200 feet. This group crops out in all but a few townships. During the period when the iron furnaces were operating, a considerable amount of this limestone was used for flux. Chemically, these limestones are reported as an almost pure carbonate of lime, low in magnesia. Quarries now working these limestones produce crushed stone for road construction and agricultural lime.

Sandstone. The sandstone resources in Perry County are practically unlimited. These sandstones would serve for many constructional purposes, and some would be suitable for refractories, but up to the present they are practically undeveloped. Owing to their resistance to weathering, the outcrops of these sandstones form the higher elevations. The Pocono sandstone is exposed in the eastern part of the county, the Hamilton and Oriskany sandstones form a zigzag pattern from north to south, and the Tuscarora or Medina sandstone follows and makes all of the ridges marking the northern and southern boundaries of the county.

Some of the Oriskany sandstone is very white and appears highly suited for glass sand.

Clay and shale. Clay and shale are widely distributed. These materials are suitable for pottery and brick making, and were formerly used for those products.

PHILADELPHIA COUNTY

Area 135 square miles. Population 1,931,334

Philadephia was located in 1681 near the junction of the Delaware and Schuylkill Rivers. It has grown until the city is coextensive with the county. It is now third largest in the United States, and tenth in the world, having achieved eminence in industry, commerce, science, education, art, and literature. It is a large center for textiles, locomotives, steel, ships, street cars and many diversified manufactured products. Sixty percent of all the surgical instruments manufactured in the United States are made here. The port is one of the largest in the nation with 50 miles of waterfront where ships from all parts of the world come to deposit their cargoes at 267 docks of all kinds.

Philadelphia is the home of ten nationally known colleges offering every form of art, science, technology, and literature. These include the University of Pennsylvania, Temple University, St. Joseph's College, LaSalle College, Girard College, Drexel Institute, Curtis Institute of Music, Jefferson Medical College, Hahnemann Medical College, and Women's Medical College of Pennsylvania. In the surrounding suburbs within a small radius, there are eight other recognized and accredited educational institutions such as Beaver, Bryn Mawr, Haverford, Immaculata, Rosemont, Swarthmore, Ursinus and Villa Nova Colleges. No similar area in America has such a vast cultural background. In addition to these there are many art, textile, and vocational schools, historical museums, music conservatories, and fine libraries.

The topography, except for the bluffs along the Schuylkill and Wissahickon Creek, is gentle. Most of the old part of the city is less than 100 feet above sea level. The highest point is about 440 feet in Chestnut Hill.

The rocks of Philadelphia County consist, with minor exceptions, entirely of metamorphic schist and gneiss. These are overlain by alluvial deposits of clay, sand, and gravel along the Delaware River. The mineral resources of the county are entirely non-metallic, consisting chiefly of stone products.

Clay. At several places along the Delaware River in Philadelphia, residual clay, probably weathered from the pre-Cambrian rocks, occurs in fair-sized pockets 20 to 100 feet above sea level. The clay has been used to manufacture brick. There are probably other deposits of this clay along the river area which could be used. The northern part of the county has no clay of commercial importance.

Sand and gravel. The terrace deposits along the Delaware River, consisting in part of the Quarternary Pensauken and Cape May sands and gravels, could supply abundant sand and gravel for construction purposes. A small amount of exploration work would be necessary to outline deposits of sufficient size and homogeneity.

Stone products. The Wissahickon gneiss and schist have been quarried at many places for building stone. These rocks make very attractive stone and are in popular use over a wide area. Some are adaptable to ornamental and monumental purposes. Reserves are practically unlimited.

Some of the gneiss and small areas of tough gabbro also make excellent crushed stone for road metal.

PIKE COUNTY

Area 545 square miles. Population 7,452

Pike County borders on New York and New Jersey in the northeastern part of the State. It is sparsely populated and has only two boroughs, Matamoras with 1,735 people and Milford with 901. Much of the county is densely forested. Camps and summer resorts are common along Delaware River and near the numerous lakes, ponds, and waterfalls.

Most of the county is part of the great Pocono plateau. At the eastern edge of the plateau an escarpment slopes from about 1,800 feet down to about 900 feet above sea level. The lower surface terminates at the cliffs that in many places tower 600 feet above the Delaware River. Railroad transportation is furnished by the Erie and the Delaware Valley. The Roosevelt Highway (U. S. 6) and other routes traverse the county, which has 217 miles of improved highways.

Thick deposits of glacial drift cover the county in most places. Along most of its course along the county boundary Delaware River flows over a buried valley filled with glacial outwash. Well-defined terraces occur along the river in many places.

The rock formations exposed in Pike County range from Honesdale sandstone of the Catskill group down to the base of the Onondaga group. The Catskill continental group crops out over most of the county, except for a strip about 3 miles wide along Delaware River, where the Portage group, Hamilton formation, and Marcellus shale crop out. The Onondaga formation occurs only at the tristate monument on the east bank of the river from Matamoras.

Rocks. The geologic structure is relatively simple. At the Wayne County line the rocks are horizontal, but farther south along Delaware River the rocks dip 5°-8°N. No major folds occur in the county, but there are a few minor folds of local extent, such as the Lackawaxen anticline and the Shohola syncline.

Mineral resources. Mineral resources are few. Glacial clays widely distributed probably could be used for making common brick. Careful selection of the softer shales on the plateau would, no doubt, yield material that could be used in making brick. Tests of the softer, generally dark gray shales of the Marcellus division along Delaware River indicate their suitability for making low-grade face brick. As the county is mostly forested and thinly populated there is little local demand for brick.

There are no limestones of any importance in Pike County. The likelihood of oil or gas being found in commercial quantity is negligible or nonexistent, Search for gold, silver, copper, iron, lead, and zinc ores, as might be expected, has been fruitless.

The quarrying industry, idle in 1943, has been largely devoted to the production of flagstone and curbstone. Flagstone, notable for their size, have been found along the Delaware River and used in New York City. The market for flagstone is now chiefly in connection with pattern floors.

Most of the quarries in the fine-grained hard sandstone, called bluestone, that have produced flagging and curbing are along the Delaware and Lackawaxen Rivers because of accessibility to a railroad. Pond Eddy and Shohola have shipped bluestone for many years. The Delaware River flags in the Catskill formation are extensive and widely distributed.

Sandstone suitable for building is available in all the townships, except where deeply buried by glacial drift. It splits clean on the bedding planes and makes good quarry-faced ashlar. Buildings of local sandstone may be seen at Milford, Milrift, Lackawaxen, and bridge piers at Shohola. The mill in the gorge south of Hawley is built of greenish sandstone quarried on the Pike County side of the gorge.

Some of the tough sandstone in the county is suitable to crush for concrete aggregate.

Sand and gravel for building can be obtained from the glacial drift generally within a short distance of any place where needed.

POTTER COUNTY

Area 1,092 square miles. Population 18,201

Potter County is in the middle of the north tier. It is the top of the world in a sense for the streams heading in Potter County drain to the Gulf of Mexico by Allegheny River, to the Atlantic by the Susquehanna, and to the Gulf of St. Lawrence by Genesee River. Because of its headwater position, the streams have not cut so deeply as in most of the adjacent counties. Farms occupy 38 percent of the surface. Only 74 percent of it is in forests as compared with 89 percent in McKean County. Five railroads and 316 miles of improved State highways provide transportation.

Topography. The whole county is high above sea level, considerable areas being above 2,300 feet. The valleys of the main streams are steep-sided, 700 or more feet deep, but many of the valley slopes are of moderate steepness. Some of the valleys have flat bottoms up to half a mile wide, as at Shingle House, Genesee, Roulette, and Coudersport.

Rocks. Several structural basins cross the county from northeast to southwest, in which occur the lowest Coal Measures with their coals, clays, and sandstones. Between the synclines the folding brings up the Pocono and even the Catskill and Chemung rocks to the tops of the hills. Much drilling for gas at the Oriskany horizon has revealed the strata below outcrops. This is brought out in the following table:

ROCKS OF POTTER COUNTY

	Feet
Alluvium	
Glacial deposits	
Pottsville series	0-150
Mauch Chunk shales	50
Pocono (and Oswayo)	350-650
Catskill red beds	350-600
Chemung	1850-2600
Portage	1800-3000
Genesee	100-200
Tully limestone	40-65
Hamilton	530-580
Marcellus	0-115
Onondaga limestone	5-30
Oriskany sandstone	5-30
Helderberg limestone	65
Cobleskill	5
Salina	300

Mineral resources. The chief mineral resource of Potter County to date has been natural gas. Previous to 1931, gas had been obtained from the Bradford sands at depths from 900 to 1,300 feet. In 1931 drilling to the Oriskany sand revived the gas industry. After reaching 2½ billion cubic feet in 1922, it had dropped in 1931 to 841 million cubic feet, but in 1932 jumped again to over 2 billion cubic feet. Many wells have been drilled to the Oriskany sand since then, opening up the Harrison and Ulysses fields on the Harrison anticline, the Hebron and Ellisburg and three small pools on the Hebron anticline, and the Sharon and State Line pools on the Smethport axis. The Medina sand has been tested in the county with negative results. Two small oil pools have been found, in which production has ranged from 13,612 barrels in 1921 to 3,122 barrels in 1929, and risen to 11,031 barrels in 1936 and since then has declined. An estimated 650,000 barrels can still be gotten from these two pools by intensive repressuring.

The small basins of Coal Measures on the hilltops should be examined for coal, clay, and sandstone. Because of the small size and shallowness little can be expected from these basins, but until they have been thoroughly explored, it would be misleading to say that they contain nothing of value. The underlying strata do not give much promise of rocks or minerals of value. Doubtless, some of the shales are suitable for brick and the glacial drift that covers the northeast corner of the county should yield sand and gravel and possibly clays.

SCHUYLKILL COUNTY

Area 783 square miles. Population 228,331

Schuylkill County is in the Anthracite Area. Originally, it contained more than one-half of the anthracite in the State and today contains nearly two-thirds of the anthracite still available. This fuel and an abundance of labor has resulted in manufacturing industries which, in value of production, almost equal that of mining. The county produced 11,855,291 tons of coal in 1940, valued at $42,757,500. Schuylkill County will probably be mining coal long after the coal of every other county in the State has been exhausted. Pottsville, the county seat, had 24,530 people in 1940.

Topography. Aside from two areas underlain by Devonian and Upper Silurian rocks which weather down into lower and more fertile lands, most of the county is underlain by the hard sandstones of the Coal Measures and of the Pocono and Catskill groups, all highly folded, which produce a wilderness of mountains and rocky lands called "St. Anthony's wilderness". The mountains range from 1,300 to 2,100 feet above sea level in comparison with Schuylkill River, which leaves the county at 385 feet. That 65 percent of the county is in forests reflects its mountainous character.

Rocks. The south county boundary follows Kittatinny Mountain formed by the basal Silurian Tuscarora sandstone, though as a rule the sandstone crops out south of the county line. Between Kittatinny and Second Mountains, the Middle and Upper Silurian, and all of the Devonian crop out, making a broad, rolling lowland with hills having altitudes from 700 to 1,200 feet. From Second Mountain northward, except at the west end of the county, the rocks consist of the Mississippian and Pennsylvanian series, highly folded. The productive Coal Measures form a narrow zone across the middle of the county, the Southern Anthracite field; the eastern end of the Western Middle field lies farther north and the western end of the Eastern Middle field occurs in the northeastern townships. The exposed rocks are between 15,000 to 20,000 feet thick. The Coal Measures have a thickness of 2,800 feet, plus up to 1,400 feet of Pottsville rocks. The total thickness at any one place probably does not exceed 3,500 feet. The Tuscarora sandstone 1,600 feet above sea level at the south line of the county is estimated to be 14,000 feet below tide near Pottsville. The lowest bedded rocks at this point are possibly more deeply down-folded than at any other point in the State or in the Appalachian Province.

Mineral resources. Coal. Anthracite is the great mineral resource. Starting with an original 12,100,000,000 net tons, of which 1,260,000,000 tons have been mined, it is estimated that 10,007,000,000 net tons remain, of which 4,903,000,000 are recoverable at the past percentage of recovery. Thirty-six beds of coal are listed. The following sections of coal beds at Pottsville show the richness of the county in coal:

COALS AT POTTSVILLE

	Ft.	*In.*
Peach Mountain	4	0
Little Tracy	2	2
Big Tracy	14	0
Little Clinton	3	3
Clinton	3	8
Little Diamond	3	8
Diamond	13	4
Little Orchard	2	5
Orchard	4	1
Primrose	13	9
Mammoth	56	5
Skidmore	9	6
Buck Mountain	8	0

The beds all tend to split irregularly and widely. The Mammoth bed ranges from 50 feet of solid coal near Shenandoah to 292 feet in four benches not far away, and a single parting may thicken to as much as 145 feet. At Pottsville the Mammoth bed is 103 feet 3 inches thick, including seven splits that total nearly 47 feet. In places partings up to 125 feet are all conglomerate. The change from a solid bed to a widely parted bed may occur in a very short distance.

The anthracite of this county varies from 7.5 percent of volatile matter at the west corner to less than 2 per cent at the northeast edge. The huge quantity of anthracite mined annually in this county is augmented by a notable amount recovered by dredging in the Schuylkill.

Sandstone. Quarries in North Manheim and North Union Townships produce crushed stone for concrete and road metal, and sandstone in various formations, including the Pocono sandstone, Pottsville conglomerate, and the Coal Measures, has been used for building stone. Suitable material for construction is available in all parts of the county.

Limestone. The Helderberg limestone crops out in a narrow band at the foot of the north slope of Kittatinny Mountain from the Berks County line south of Andreas along the south side of Lizard Creek, past New Ringgold and Orwigsburg to Schuylkill Haven. Here it turns back and underlies hills east of Pine Creek, crosses the Schuylkill below Auburn, and follows a direct course south of Bear Creek, Pine Grove, and Suedberg to the Lebanon County line near Swatara Gap. Thus the limestone crops out all the way across the southern part of the county.

Nevertheless, quarries were opened in only a few places many years ago to get stone for agricultural lime. In recent years limestone has been quarried near Andreas and a mile east of Schuylkill Haven for concrete aggregate and road metal.

Shale. Practically all parts of the county contain shale suitable for making brick, and some of it is adjacent to a railroad. Soft red shales of the Mauch Chunk formation occur in five distinct areas, and shales of Middle Devonian and of Silurian age make bands across the southern part of the county. Bricks are made at only one place, Auburn, where the Bloomsburg red beds are used. The product is face brick of various colors and textures, radial chimney brick, and paving block.

SNYDER COUNTY

Area 329 square miles. Population 20,208

Snyder County borders Susquehanna River for 20 miles from opposite Northumberland to McKees Falls, and extends west to Mifflin County.

Selinsgrove is the largest borough and Middleburg is the county seat. Paved highways are numerous and a railroad crosses the county from Selinsgrove to the southwest corner; also a railroad follows the west bank of the river north from Sunbury.

The oldest rocks outcropping are Upper Ordovician Martinsburg shale and the youngest are Upper Devonian Catskill red sandstone and shale. The Tuscarora sandstone makes Jacks and Shade Mountains. The rest of the county is generally hilly, the largest generally level area being in the Helderberg limestone and Devonian shale between Centreville and Port Ann.

The mineral output of the county consists of brick, crushed stone, and lime. Building stone and iron ore are possibilities.

Limestone. The Helderberg limestone crops out in three belts across the county and was opened in the previous century in many, perhaps hundreds, of places to get stone for making agricultural lime. Both the hard blue and thin-bedded stone were used. In places it was practicable to work only 15 to 20 feet of stone between useless shaly or siliceous beds; in other places as much as 100 feet of fair grade stone occurs with only occasional thin shale partings.

In most places the beds dip rather steeply. Some stone is suitable for building and has been used in a few farm houses. Much of it will make crushed stone for roads. Very little is burned for lime at present, but the stone is well distributed and abundant.

Sandstone. Although the Tuscarora sandstone and the sandstone members in the other formations are available from one end of the county to the other and suitable for common rural uses of building stone, none has been used except for rubble foundations of houses and barns. The colorful Tuscarora sandstone has been used in adjoining counties with success.

The Tuscarora is a quartzite, carries 97 percent silica, and in places up to 65 percent of the floe is usable for silica brick.

Shale. Clinton and Middle Devonian shales are abundant and usable for common and face brick and paving blocks. They are readily accessible along the railroad and along the main east-west highway, Route 522. Brick plants at Beavertown and Paxtonville demonstrate the use of the local shale.

Iron ore. The horizon of the Clinton iron ore beds, including the Danville beds and the Sand Vein ore, extends from Centreville to the western boundary of the county, and on both sides of Shade Mountain eastward to within about three miles of Selinsgrove. The ore was mined extensively in the 1870's but only one mine was active in 1888, and production ceased not long after. Several mines were on Block Ore Ridge near Adamsburg. The ore beds dip steeply in most places; the ore is soft at the surface and hard at depth. It varies in thickness and quality along the strike.

The Danville bed has been worked where it was 5 to 18 inches thick, dipped 40°, and was of fair quality. In other places it is only 6 inches thick and lean, or is only an iron-bearing limestone. The Sand Vein in Spring Township was mined where 28 inches thick and carried 32 to 40 percent metallic iron and 24 to 35 percent silica. At another mine it was 26 inches thick and carried 16 to 20 percent iron, and at still another mine 22 inches thick and 35 to 48 percent iron.

The Sand Vein north of Troxel measured 16 to 18 inches but was siliceous. The iron ores have not been found in good quality and thickness in the west end of the county.

Considerable tonnages of iron ore have been mined and smelted in this county. Extensive deposits remain, but the beds are thin and not high grade.

SOMERSET COUNTY

Area 1,084 square miles. Population 84,957

Somerset County is in the south tier; third from the west line of the State, and in the Allegheny Mountains Area, except the southeast corner. It extends from Allegheny Mountain on the east to Laurel Hill on the west. The Court House at Somerset is 2,190 feet above sea level, higher than any other public building in the State. Berlin at 2,322 feet is the highest borough and Pocahontas at 2,660-2,730 feet is the highest settlement in the State. The principal mineral resource is coal. Three railroads, the Pennsylvania Turnpike, and U. S. Routes 30 and 219 cross the county, which also had 647 miles of improved State highways.

Topography. Because of its high altitude, this county is known as "The Roof Garden of Pennsylvania." It is a dissected plateau sloping from 2,800 feet above sea level on Allegheny Mountain at the northeast corner to 2,000 feet on the west side, where Laurel Hill rises to 2,800 feet and higher on the west boundary. Negro Mountain projecting into the county from Maryland culminates in Mt. Davis, elevation 3,213 feet, the highest point in the State. Where Youghiogheny River cuts through Laurel Hill at 1,270 feet is the greatest relief, a descent from 2,500 feet in six-tenths of a mile. Large parts of the county are more than 2,200 feet above sea level. The southeast corner of the county east of Allegheny Mountain is in the Ridge and Valley Area. Little Allegheny Mountain on the southeast boundary reaches 2,100 feet and Big and Little Savage Mountains are 2,400 to 2,800 feet high. The strongest relief in this corner is from 1,220 feet at Wellersburg to 2,889 feet on Big Savage Mountain 2½ miles west. The lowest point in the county is 1,140 feet where Wills Creek crosses the east boundary. The higher hills in the hilly country between Allegheny and Savage Mountains are around 2,400 feet.

Stony Creek drains the northern part of the county to Conemaugh River. Wills Creek in the southeast townships flows to the Potomac River. Casselman River drains the southern part of the county into the Youghiogheny at Confluence.

Rocks. The rocks in Somerset County range from the Chemung formation of Upper Devonian age to the lower members of the Monongahela formation. The Chemung formation, brought up by an anticline, is exposed in a belt three to four miles wide in Allegheny, Northampton, Larimer, and Greenville Townships. About 2,200 feet of greenish to reddish sandstone and sandy shale are exposed. Bright red shale and red sandstone of the Catskill formation border the Chemung outcrop in the same townships and dip at angles of 12° to 20° beneath the massive Pocono sandstone, which forms the crest of Little Savage and Bearwallow Mountains on the east and a series of knobs and ridges on the east flank of Allegheny Mountain. The Catskill beds are about 2,500 feet thick. The upper members are exposed also where the Youghiogheny cuts through Laurel Hill, and in a small area on Shoemaker Run in Addison Township completely surrounded by Pocono rocks. The crests of Allegheny Mountain and Laurel Hill in the northern part of the county also are formed of the massive Pocono sandstone, which is about 1,200 feet thick.

The Loyalhanna sandy limestone about 50 feet thick, and about 450 feet of overlying Mauch Chunk red shales occupy the valley between Big and Little Savage Mountains. They are high on the east slope of Allegheny Mountain as far north as Shade Township, and on the west slope there and in Ogle Township. They occur also on the east slope of Laurel Hill north from Jefferson Township and at the Youghiogheny Gap, in the gorge of Casselman River through Negro Mountain, and in the northern and western parts of Elklick Township on the Negro Mountain anticline.

The thick-bedded gray Pottsville sandstone, up to 200 feet thick, stands nearly vertical in Little Allegheny Mountain, dips under the Wellersburg basin and rises to the crest of Big Savage Mountain. It forms most of the crest of Allegheny Mountain, but is on the west slope in Shade and Ogle Townships. It caps Negro Mountain from the Maryland line up to and a little beyond Casselman River, and forms part of the crest of Laurel Hill, but is on the east flank north of Jennertown. It crops out in the valleys of Shade and Stony Creeks to the north line of the county.

The Allegheny formation about 300 feet thick and the Conemaugh formation averaging 850 feet are the surface rocks in a large part of the county. They occupy the Johnstown-Confluence and the Berlin major synclines or basins, and also the small Wellersburg basin. Small areas of Monongahela rocks, including the Pittsburgh coal, occur in each of the three synclines: at Wellersburg, between Berlin and the Maryland line near Salisbury, and near Glessner in Jenner Township.

Mineral resources. Coal is the outstanding mineral resource. Thirty-eight operators with 6,464 employees working 57 mines in 1940, produced 5,939,809 tons, valued at $12,288,400. Starting with an estimated 6,700,000,000 tons, it is computed that 400 million tons have been recovered or lost, leaving as still recoverable 770 million tons of coal over 3 feet thick, nearly 1,700,000,000 tons between 2 and 3 feet thick, and 2,065,000,000 tons to be recovered from coal less than 2 feet thick in the distant future. Of the recoverable coal over 2 feet thick, it is estimated that one-half is in the Upper Kittanning bed, which is strange inasmuch as that bed is not commonly workable elsewhere. More knowledge based on many more drill records might reduce these reserves very materially. The Upper Kittanning coal ranges from 2½ to 6 feet in thickness.

Next in importance is the Lower Kittanning or Miller bed, which, though not so thick, is probably much more persistent. It is 2 to 5 feet thick. Most of the mining is on coal between 3 and 3½ feet thick. The Upper Freeport is also a persistent bed, but is likely to be under rather than over 3 feet thick. The Lower Freeport bed is 1 to 4 feet thick. The "Brookville" coal is locally a thick and workable bed of up to 6 feet, but commonly broken up with partings. The volume of Pittsburgh coal was never large and is probably nearing complete exhaustion. The coals are mainly of low-volatile rank, ranging in volatile matter from 12.0 to 21.4 percent, fixed carbon 64.4 to 79.0.

Natural gas has been found in the county only in small quantity. The largest well, on the W. H. Miller farm, is estimated to have produced 1½ million cubic feet when first drilled, at a depth of 2,660 feet, from the middle of the Catskill rocks. This well is in Quemahoning Township 1½ miles southeast of Ralphton and in a syncline. Several other tests did not show enough gas to encourage further drilling, considering the distance pipe lines would have to be built to make them of value. Wells on anticlines might be more successful.

The clays and shales of the county have been little developed. Building brick and various tile are made only at Windber and Springs. No reason is known why flint clay should not be found at the horizon of the Mount Savage clay of Maryland (Mercer) and a little clay at the horizon has been mined on the eastern border of the county at Williams. This horizon might repay testing wherever it crops out. The same is true of the Lower and Upper Kittanning, and Upper Freeport (Bolivar) horizons. Some or all of these should yield flint and plastic clay of value in places, if not generally, as shown by the production of clay at Fort Hill, a few miles east of Confluence. Likewise, some of the shale of the Allegheny and Conemaugh formations should prove suitable for brick and tile, especially when used with clays from under the coal beds.

Sandstone suitable for rough structural work is abundant and widely distributed. The most valuable are the Kittanning, Homewood, and Connoquenessing sandstones. Large blocks scattered on the surface are broken for building stone. No place has been noted as yet where the sandstone is free enough from iron and of attractive color and grain to render it of high commercial value.

Limestone occurs in the county in more than a dozen different beds, all but two of them in the Coal Measures. All have been widely burned in open heaps on a small scale for agricultural lime. A few kilns burn lime intermittently. The Loyalhanna sandy limestone and the fossiliferous Greenbrier limestone of Mississippian age are the only ones that are more than a few feet thick. The Greenbrier is up to 40 feet thick with interbedded shales, and a 14-foot bed has long been mined and burned in kilns east of Salisbury. The Loyalhanna limestone is up to 50 feet thick. It is mined near Garrett for crushed stone and a quarry was opened near the east end of Laurel Hill tunnel in order to provide crushed stone for the Turnpike. The long outcrops of this limestone offer opportunity for unlimited production of crushed stone. It is suitable also for making paving blocks.

Sand and gravel occur along the streams. The only recent production is at Boswell.

Iron ore occurs as balls or thin irregular beds of carbonate at a few horizons in the Coal Measures. Attempts were made to use this ore in the early days, and although analyses show 36 to 40 percent metallic iron, the fact that the deposits are only 15 inches to 2 feet thick made their use unprofitable. The iron deposits are thought to have no present value.

SULLIVAN COUNTY

Area 478 square miles. Population 7,504

Sullivan County is best known perhaps as the location of the Bernice coal field and of Eagles Mere, a popular vacation resort. Though less well known than the Mauch Chunk area, Sullivan County may well claim to be the Switzerland of Pennsylvania because of its high relief and its glacial lakes and ponds. It includes some of the highest land in northern Pennsylvania, adjoining valleys at relatively low levels. The fire tower of North Mountain at 2,593 feet is 1,800 feet higher than Muncy Creek below Beech Glen two miles away. Loyalsock Creek above Forkville runs in a narrow valley 500 to 800 feet deep. Fishing Creek just above Jamison City near the southeast corner of the county is 1,250 feet below the adjacent hilltops at 2,300 feet, in one place only 2,200 feet horizontally from the creek. This high relief is because the massive Pottsville and Pocono sandstones lie nearly flat and have resisted erosion. Although scenery may not be classed as a mineral resource, it is certainly a natural resource in this county.

Rocks. The rocks exposed at the surface include the Chemung to Pottsville sandstones and shales. Two anticlines and two synclines give gentle structure to the nearly horizontal rocks. The outcrops, therefore, lie in nearly parallel bands. Chemung rocks occur along the north boundary in the northern parts of Cherry and Forks Townships. Catskill beds are mainly in the valleys of Elk, Little Loyalsock, and Muncy Creeks. These softer rocks have been eroded to great depth. The massive Pocono sandstone makes the high land in most of the county. Several small areas of Pottsville sandstone encircled by narrow outcrops of Mauch Chunk shale occur between Mildred and Lopez and two patches farther west in the northern syncline.

Mineral resources. The principal mineral resource is coal. It occurs in several basins of which the Bernice basin is much the largest. That basin holds two mineable beds, A and B. The A bed is generally about 2 feet thick. The B bed is commonly split into three benches, averaging 3 and 4 feet thick. The coal is of semi-anthracite rank, with 76 to 83 percent fixed carbon. The coal west of Bernice is a little higher in volatile matter and lower in fixed carbon. Mineable coal in the Bernice basin alone is estimated at 4 million tons.

Fire clays up to 15 feet thick are reported as associated with the coal beds, though other sections show the coal resting directly on sandstone. Sandstone is abundant and suitable for local construction. It has been used as rubble and as dressed stone. Summer cottages might be built of the Pocono sandstone that strews the surface in loose blocks. Red flagstones could be quarried on Muncy Creek and in the northern townships. Soft red shales are abundant and possibly some of the shales associated with the coal beds would be suitable for clay products. Small deposits of bog manganese and iron in Cherry and Colley Townships might be used for purifying artificial gas or in making paint. Limestone, oil, and gas are believed to be lacking in the county.

SUSQUEHANNA COUNTY

Area 836 square miles. Population 34,893

Susquehanna County lies entirely in the High Plateau Area. Susquehanna River loops into the northern edge of the county at an elevation of about 900 feet. The surface is a closely irregular network of hills rising to an altitude of 1,600 to 2,100 feet, largely under cultivation, dotted with small lakes, many of them hanging on the flanks of the hills at elevations of 1,400 to 2,000 feet.

Rocks. Except in the southeast corner and the Chemung rocks in the deep valleys along the north boundary, all the rocks in the county are the Catskill (Devonian) type of land-laid sandstone and shale, mostly red, lying nearly horizontal. Toward the southeast corner a dip to the east brings to outcrop in succession, the uppermost Devonian rocks—the Damascus red shale, Honesdale sandstone, Cherry Ridge red beds, Elk Mountain sandstone, and the Mount Pleasant red shales. Then, just in the corner, the Pocono, Mauch Chunk, and Pottsville rocks surround the Coal Measures forming the northern end of the Northern Anthracite field.

Mineral resources. Anthracite occurs only near Forest City. The quantity remaining in the county is very small. However, its mining is still the county's major mineral industry. The two principal coal beds are 4½ and 6 feet thick. The sandstones just listed, and others in the New Milford formation which underlies most of the county, supply building stone for rough structural purposes. Formerly this county cut and marketed a considerable quantity of flagstone of which the supply is abundant. Sand and gravel is abundant as all of the county was overrun by the glaciers during the Ice Age. This material is dug near Susquehanna for building purposes. In the Cherry Ridge formation are 5 to 10 feet of impure limestone that has been used for making agricultural lime. It has no other commercial value. Most of the bedded shales and glacial clays are suitable for making brick, drain tile, flower pots, and some types of stoneware. A brickyard operated near Lanesboro for 30 years is idle.

TIOGA COUNTY

Area 1,150 square miles. Population 35,004

Tioga County is a north tier county, just east of the center of the north State line. It is all in the High Plateau Area. In 1930 this county came into the limelight like a nova through the discovery of a very rich and short-lived gas field in a northern township. The county has long been known as a coal-producer. It produced a little oil near Gaines for many years and has had a small output of other minerals. In contrast with the more typical High Plateau Area farther west, 62 percent is in farms and only 51 percent in timber. It is well supplied with railroads.

Rocks and Topography. The topography is controlled by the stratigraphy and structure of the rocks. The outcropping rocks consist of the basal Pennsylvanian, Mississippian, and Upper Devonian. At the top of the section of rocks is 180 feet of Allegheny and Pottsville rocks, hard sandstone, shale, coal, and clay, including the Seymour (Clarion?), the Bloss (Mercer) coal and clay and Bear Creek (Sharon) coal; the Mauch Chunk 0 to 40 feet thick, then a thick zone of hard Pocono sandstones, including Oswayo, 1,100 feet thick; then the Catskill of intermediate hardness, and underlying these a great thickness of Devonian rocks.

DEVONIAN AND SILURIAN OF TIOGA COUNTY

	Feet
Catskill (Cattaraugus?) group	500
Chemung group	2000
Portage	1750
Genesee group	150
Tully limestone	80
Hamilton	700
Marcellus black shale	200
Onondaga limestone	20
Oriskany sandstone	50
Helderberg group	250
Tonoloway	50
Salina group, including salt	2270
Vernon shale	618
Clinton group (estimated)	650
Medina sandstone	

Three basins or synclines cross the county, running north of east, one through Blossburg, the next through Middlebury Center, the third about follows Cowanesque Creek. Each is held up by massive sandstone like the rims of elongated saucers, the edges rising to

2,200 or 2,300 feet above sea level. Between these basins, the underlying softer rocks, brought up by strong anticlines, have worn down to rolling uplands between 1,000 and 1,800 feet above sea level, where the hills, like subdued potato hills on a large scale, rise with moderate slopes 100 to 500 feet above the adjoining valleys. Some of the valley bottoms are flat. Where the streams cross the rims of the basins, the valleys are steep-walled and from 700 to 900 feet deep. The glaciers have induced many changes in the drainage in the county, old channels abandoned which today give low-grade road ways, and new channels opened up, such as that of Pine Creek below Ansonia, "the Grand Canyon of Pennsylvania." Upper Pine Creek formerly ran to Tioga River by Marsh and Crooked Creeks, but was forced to find outlet to the south when the ice closed its old outlet.

Mineral resources. Coal. A railroad from Blossburg to Tioga finished in 1840 gave outlet to the coal of that basin. Production increased until, in 1870, it was more than one million tons and continued around that amount until 1892 when a decline began. In 1928 recorded production was only 110,224 tons; it was 339,745 tons in 1941. It is estimated that 26 million tons may still be obtainable from beds over 2 feet thick and 45 million tons from thinner beds. Detailed surveys might show this to be too conservative.

Oil and gas. Two small oil fields were discovered near Gaines just at the end of the last century, wells yielding from a few barrels up to 2,100 barrels a day. Some of the wells were short-lived, others produced for many years. Small pockets of gas have been found from time to time by drilling to shallow sands. But in September 1930, a well carefully located on the Sabinsville anticline in Farmington Township came in, yielding 22 million cubic feet a day. It was followed by many others, one of which was stated to have blown off 80 million cubic feet a day until gotten under control. The field did not last long. Test drilling undertaken on the Wellsboro and other anticlines, and on the Sabinsville anticline east of Tioga River, gave only negative results. It cannot be said that all of the gas has been taken out of the Oriskany or higher sands, but the many holes that have been drilled without results on carefully selected locations do not encourage further drilling. It was found that the major structures are broken by faulting, involving displacement up to 700 feet. Of two wells close together, one might get plenty of gas and the other go several hundred feet deeper to the same sand and get only salt water.

The clays and shales of this county have not been adequately studied. There is no known reason why the clays under the coals of the Blossburg, Arnot, and Antrim basins and their accompanying shales should not be suitable for making brick, tile, and terra cotta. Some of the clays may be suitable for fire brick.

Sandstone has furnished much flagstone and some building stone. The county has numerous examples of the use of local stone, especially the Pocono. Some of the sandstone has been used in the past for making glass; glass making is still a large industry at Wellsboro. Sand and gravel are abundant and are dug for local use.

UNION COUNTY

Area 318 square miles. Population 20,247

Union is a wedge-shaped county, 22 miles along the West Branch of the Susquehanna River north from Sunbury, tapering to only 3 miles at the west where it butts on Mifflin County. Lewisburg and Mifflinburg are the largest boroughs. Transportation is afforded by highways in the main valleys and by railroad along the river and west from Lewisburg.

Bedrock includes the succession from Martinsburg shale of Ordovician age to Upper Devonian Catskill beds that crop out in parallel east-west belts and fingers. The mountains are tough sandstone and the large valleys are in limestone and limy shale.

The principal mineral resources are limestone for crushed stone and lime, sandstone for building and crushed stone, and clay and shale for brick. Iron ore is present in thin beds.

Limestone. The Helderberg limestone crops out across Gregg Township in a belt 4 miles long; a loop of it runs west from Lewisburg 4 miles on the south side of Buffalo Creek and then returns to the river north of the creek. An east-west ridge of limestone 8 miles long has its center at Mifflinburg; and a fourth outcrop extends east from New Berlin 7 miles to the river, and west 3 miles to enter Snyder County.

Fifty years ago there were many quarries on each of these outcrops. The stone was burned for mortar and plaster, and for agricultural lime. In recent years the few quarries operated are near Lewisburg and Winfield, and the product has largely been crushed stone for roads. The largest quarry in the county is half a mile southwest of Winfield.

Sandstone. The Tuscarora sandstone makes all the prominent mountain ridges. Some of it is 97 percent silica and suitable for silica brick. Floatstone suitable for building and crushed stone is abundant and has been used, notably at Laurelton State Village.

Shale. The Clinton or Middle Silurian shales offer the best chance for development as brick shale. They underlie a large area in much of the lowlands and along the railroad that follows Susquehanna River. They also could be developed on the railroad west from Lewisburg to Weikert. Middle Devonian and Catskill shales also are usually suitable for making brick. No brick or tile are made in the county.

Iron ore. The Clinton fossil iron ore crops out on the south side of Shamokin Mountain from Winfield to Centreville, and on the north side from the river nearly to the west boundary; thence zigzags across the county to the river north of White Deer. It extends in a straight line across Gregg Township on the north flank of South White Deer Ridge. Here it was mined many decades ago where it dipped 35° and was in two benches six and sixteen inches thick. Nearby it was too siliceous.

The Clinton or Danville ore near Winfield was mined where 20 inches to 3 feet thick and dipping 35°. Between the river and New Berlin the bed dips 45° and ranges in a short distance from 4 to 18 inches thick; it may be low grade. The ore is soft at the surface and hard below water level. One analysis of hard ore showed iron 34 percent, lime carbonate 39, carbonate of magnesia 2.5, phosphorous 0.358, sulphur 0.004. These descriptions of the iron ore are representative for the county. Although the Clinton ore in this county must be considered as part of the State's iron ore reserve, it is unlikely to have commercial value for many years.

VENANGO COUNTY

Area 675 square miles. Population 63,958

Venango County is in the northwestern part of the State halfway between Pittsburgh and Erie and in the Upper Allegheny Area. This county, whose history is associated with the discovery of petroleum, maintains an important position in producing and refining that commodity. Oil City, the largest municipality has a population of 20,379; Franklin, the county seat, has 9,948 people.

Venango County is to the oil industry what Pittsburgh and Allegheny County are to the coal and steel industries.

The oil industry began in this county and in this continent with the drilling of the Drake well on Oil Creek south of Titusville in 1859.

Topography. The county has rather rugged topography with only small flat areas along the valleys and on the uplands. A few hills along the eastern county line are more than 1,700 feet above sea level, but along the western boundary most of the highest hills are only about 1,500 feet.

Allegheny River and French Creek and their tributaries drain the county. Some of the streams in the northwestern part flow on deep glacial valley filling, but most of the streams flow in bedrock valleys. The steepest slopes occur along Allegheny River, where the valley walls in places rise abruptly more than 500 feet. In pre-glacial time this area drained northwest by the French Creek route reversed.

Rocks. The rocks exposed in Venango County extend from about 100 feet above the Vanport limestone member of the Allegheny formation down to and including a part of the Pocono group. The Pottsville formation constitutes the surface rocks in almost all the county. However, all the major streams have cut through the Pottsville and exposed the underlying Pocono. In the southern part of the county the Allegheny formation caps the higher hills.

The exposed rocks include the Vanport limestone, several coal beds, the Homewood and Connoquenessing sandstones with the Mercer member between them, the Patton red shale, and Mississippian strata down to the Corry sandstone.

Below these rocks that are exposed at the surface are the Devonian strata, which are the source of oil and gas. Under the red Riceville (Bedford) shale, about 90 feet thick is the Venango oil sand group, 280 to 310 feet thick. It includes three sandy zones, the so-called First, Second, and Third oil sands. These are split up into two or more divisions each. Farther east and south, several other sands appear below these, of which only the Fourth sand is found in this county. In some areas the Tiona ("Speechley") is present and productive. One drill hole in southern Venango County found the Oriskany sandstone absent.

Mineral resources. Oil is and for some time will be the leading mineral resource of this county. The primary production of oil in the county has nearly ceased except as long-lived wells continue to produce a small fraction of a barrel daily. Many thousands of acres are listed as abandoned. Oil to be gotten simply by drilling and pumping is about exhausted. The oil industry, however, has been very active in the use of repressuring methods and has had considerable success in securing a large volume of the oil left in the rock after primary production has ceased. The oil is forced out of the rock by air or gas introduced under pressure.

It is estimated that 114,600 acres of the county are underlain by oil-producing rocks and that the original supply exceeded 700 million barrels. About 275 million barrels of this could be recovered if the market price for oil were high enough. About 72 million barrels are recoverable under present conditions; this is about one-fifth of the immediately recoverable oil in the State. Recent gas production has declined from 20 billion cubic feet in 1921 to about 2 billion cubic feet in recent years. Much of the gas is used for repressuring oil wells.

A shaft has been sunk near Franklin to a depth of 429 feet to test the quantity of oil to be had by drilling horizontally in the oil sand from the bottom of the shaft. Other methods of recovery are being considered to maintain the county's reputation as the world's leader in oil recovery.

Of the other mineral resources, sandstone is of most importance. The Homewood and Connoquenessing have both been quarried. Recent quarrying has been mostly for glass sand. Sand and gravel deposits are abundant throughout the glaciated part of the county and in the river bottoms and benches outside the glacial boundary. Principal production is near Oil City. Coal and clay have a very minor value because of the small areas they underlie and their small volume. The shales are more abundant, especially in the Mississippian, and are suitable for brick and tile. Bricks are made at Youngsville.

WARREN COUNTY

Area 910 square miles. Population 42,789

Warren County is the second in the north tier east from Ohio. It is all in the Upper Allegheny Area. It comes next to McKean and Venango in oil production, which is its principal mineral industry, supplemented by oil refining, in which it stands fourth in the State. Natural gas, sand and gravel, brick making, and occasionally coal mining follow in that order of importance.

Topography. The relief is typically of plateau type with fairly broad but not flat uplands from 1,700 feet above sea level in the southwest corner to 2,200 feet in the northeast corner, breaking down sharply 600 to 900 feet to valleys, some broad and flat, evidently old valleys now partly filled with gravel, and some sharply incised. Some of the very narrow valleys have been cut through old divides as a result of glacial drainage changes. The preglacial drainage was toward Lake Erie.

Rocks. The exposed strata range from the Pottsville series of the Pennsylvanian system, through the Mississippian strata, and down to the Upper Devonian beds. The basal Pottsville rocks cover the hilltops in the southeastern half of the county, and Pocono rocks are in the minor valleys. The Pottsville includes the Connoquenessing sandstones, Sharon shale, a little coal and the Sharon (Olean) conglomerate. The basal Mississippian rocks cover the hills and the Upper Devonian rocks are in the valleys in the northwestern half of the county. The Mississippian rocks, including the Pocono, have mostly been removed, leaving only the lower part of the Cuyahoga and the Berea. The upper Devonian in Warren County is described as the Conewango formation, 510 to 560 feet thick. The upper part, down to the Salamanca sandstone, is called the Oswayo and equals the Riceville shale and the upper half of the Venango group farther west, and the lower part is the Cattaraugus formation from the Salamanca to well below the Venango Third sand. The "Catskill" red beds in the Warren region are only a few feet thick. Only the upper part, about 300 feet of the "Chemung" formation, 1,120 feet thick, is exposed. Below the surface, the formation includes the Warren oil and gas sands, the Glade, Clarendon, and Gartland. Farther below are the Bradford and other sands, as described more in detail in McKean County. Glacial ice overran the north third of Warren County one or more times leaving surface deposits from a few feet deep on the general upland to 250 feet or more in the filled valleys. These are moraines, terrace deposits, and valley trains, consisting of till and outwash sand and gravel.

Mineral resources. Oil. Oil is and will long be the county's principal mineral resource. Oil has come mostly from the Warren sands, the Glade and Clarendon. The upper Venango sands crop out in the area and the underlying Bradford sands thin out. It has been estimated that 55,000 acres of the county are underlain by oil-producing strata and that these beds contain 330 million barrels of oil, of which 144 million barrels could probably be obtained by present methods if costs were not a factor, but that only 35 million barrels can be obtained by known methods at present prices or a little higher, provided that repressuring is applied to all the known oil sands.

Gas. Gas production has not been large. In 1920 it reached 3 billion cubic feet, but has decreased greatly in recent years.

Coal. The basal Pottsville rocks contain one coal bed, the Sharon, that has been worked in a small way. Locally, it averages two feet in thickness and is of fair quality. No large commercial operation could be planned in this county.

Clay. Clay occurs locally in the flood plains of Allegheny River and Conewango and Brokenstraw Creeks. Glacial red and blue plastic clays in the northwestern half of the county have been used for making brick. They are suitable for common brick and tile. The Conewango shale, which crops out in the valleys of Allegheny River east and west of Warren and Conewango Creek north of Warren is suitable for brick manufacture. Some of the Mississippian Cuyahoga shales and the Devonian Chemung shales may also be used for this purpose.

Building stone. The Olean conglomerate and Salamanca conglomerate make excellent building stone. Both of these rock types and the Connoquenessing sandstone may be quarried near Warren. The Olean has broken into large blocks and strews the hillsides of much of the area south of Warren. Wherever there is a hill with thin soil cover in the region underlain by these rocks a quarry could be opened.

Sand and gravel. There is abundant sand and gravel in both the glacial outwash deposits in the valleys and in the kames and certain moraines of the upland regions. Large reserves are available from such deposits just north of Warren. The broad river flat west of Warren is underlain with sand and gravel, in places 100 feet deep. Large quantities have been produced by dredging, mostly for highway construction.

WASHINGTON COUNTY

Area 857 square miles. Population 210,852

Washington County is on the western border of the State, south of Pittsburgh, and all in the Pittsburgh Coal Area. It is estimated to have contained originally more than 11½ billion tons of coal or more than any other county of the State. It still has very large reserves of unmined coal. The Pittsburgh coal has been extensively mined throughout the eastern and northern parts of the county. It constituted about one-half of the original deposits and this readily available fuel has attracted large manufacturing industries to the area. The northern half of the county is served by three main-line railroads.

Topography. The hilltops in Washington County range from 1,300 feet along the northeast edge to about 1,480 feet above sea level in the southwest corner. The Monongahela and Ohio divide crosses the county from north to south. The highest point in the county is Scenery Hill, 1,486 feet; the lowest, 725 feet, where Monongahela River leaves the county. The surface is an intricate pattern of small valleys 200 to 450 feet deep separated by steep-sloped and narrow-topped ridges. Although the hilltops rise to about the same altitude, higher to the southwest, both valleys and hilltops are so narrow that there is little level or sublevel land in the county.

Rocks. The rocks range from the Greene group in the southwest corner to the Conemaugh group in the north end of the county. The Washington group underlies the hilltops in the eastern, middle, and northern middle parts of the county except where anticlines bring the Monongahela group to the top of the hills. The Monongahela group is at the surface in a broad belt along the east and northeast sides and much of the northern part of the county. The Conemaugh group occurs in the valleys in the north edge of the county. The Pittsburgh coal bed underlies almost the whole county, close above or below water level along Monongahela River and rising to the hilltops in the northernmost townships. The Waynesburg coal underlies the narrow hilltops throughout a wide belt in the eastern and northern parts of the county. The rocks are gently folded in northeast-southwest rolls which deepen toward the southwest.

Mineral resources. Coal. Coal is the outstanding mineral resource of the county, largely because of the great Pittsburgh bed. As usual that bed is in two parts. The roof division, which is workable in the Burgettstown region, is not workable generally. It is separated in the Burgettstown region by up to 24 feet from the main division upon which most of the mining is done. This division is from 5 to 7 feet thick and in four parts. The breast coal at the top is 30 to 40 inches thick, the bearing-in coal is 2 to 4 inches thick; and below that are the brick coal and bottom coal which together are from 24 to 30 inches thick. The separting main clay is usually from 6 to 15 inches thick. The bottom bench is commonly high in ash and sulphur and, therefore, left in the mine. Locally, the coal reaches a thickness of 16 feet where it fills channels or "swamps." The Redstone and Sewickley (Mapletown) coals are mineable only locally. The Waynesburg coal is from 3 to 7 feet thick, but carries a 1 foot clay parting near the top and usually a thin parting near the bottom. In time it should yield a considerable volume of coal. It is inferior to the Pittsburgh coal in quality. Of the several coals in the Washington and Greene groups, the Washington coal locally reaches a thickness of 7 feet, but is badly split by partings and, like the other Dunkard coals, is not considered as having immediate value.

Oil and gas. Second in value to the coal are the oil and gas deposits. Less than 40,000 acres are estimated as underlain by oil pools and over 190,000 acres are underlain by gas deposits. The oil reserves are estimated at over 144 million barrels of physically recoverable oil by present known methods, of which 35 million barrels could be recovered at present price levels or a little higher. Oil production in the county in recent years has been less than one-half million barrels per annum. At that rate the recoverable reserves will last at least 70 years, but these figures assume that secondary recovery methods are used throughout the fields. If not, the life of the field is likely to be nearer 30 years. The gas reserves cannot be readily estimated but should be considerable.

Limestone. Limestone is abundant in the county. A single drill hole has been reported as showing as much as 130 feet of limestone in the Monongahela group alone. Unfortunately, the limestones are not suitable for making chemical lime or portland cement. Generally they are suitable for ag-lime, for road building, or railroad ballast.

Other mineral resources. The sandstones, like the limestones, are as a rule too impure to serve more than a local market. In general they are flaggy. Shales are abundant, clay less abundant; both should be usable for making brick and tile. Rock salt in several beds aggregating 60 feet thick occurs more than 6,500 feet below the surface.

WAYNE COUNTY

Area 744 square miles. Population 29,934

Wayne County occupies the extreme northeast corner of the State and is bounded on the north and east by New York State. The entire county is covered with small farms and there are only three communities with 1,000 or more inhabitants—Honesdale 5,687, Hawley 1,778, and Waymart 1,095. Numerous summer resorts have been built along Delaware River and around some of the glacial lakes and ponds, 73 of which cover more than 20 acres. Large areas are in forest. Most of the county is more than 1,500 feet above sea level and 600 feet above Delaware River.

Wayne County is in the glaciated section of the High Plateau Area. It is part of the great Pocono plateau deeply dissected by the Delaware and Lackawaxen Rivers and their tributaries. The Moosic Mountains along the western border rise in several places to altitudes of more than 2,300 feet. The county slopes gently toward Delaware River in the northern part and toward Lackawaxen River in the southern part. Transportation is available over several railroads and a network of hard-surfaced roads, including U. S. Route 6, the Roosevelt Highway.

The entire county is underlain by rocks of the Catskill group, with the exception of a small area in the Moosic Mountains on the western border. There the Pocono sandstone, Mauch Chunk shale, Pottsville and post-Pottsville formations are exposed.

The geologic structure is relatively simple. The rocks are nearly horizontal. The Lackawanna syncline is the only well-defined structure; it is a gentle trough at its northern end but deepens rapidly as it approaches Carbondale. A few slight rolls of local extent interrupt the general horizontality of the rocks.

The mineral resources are few.

The county lacks limestone, but contains a rock described as an agglomerate of chips of slate and shale, fish bone fragments, fossilized wood, and a quantity of sand, all cemented together by lime. This rock is variable in composition, high in silica and generally low in lime; its black outcrop averages about five feet. It has been called the Cherry Ridge limestone and was burned in at least one kiln prior to 1880 for use as agricultural lime. Although its outcrop is extensive, only locally is the rock high enough in lime to slack on exposure after burning.

Ores of metals do not occur here. Traces of copper and nickel minerals are reported to have been found. Small quantities of wad or black oxide of manganese are scattered through the Catskill sandstones and the Pocono sandstone, but not in commercial quantity. Deposits of iron ore have not been found.

Sandstone suitable for use in building as rock-face random ashlar is abundant and widely distributed. Quarries were opened several decades ago to get stone for local use, especially near Hawley and Honesdale.

Flagstone and curbstone have been quarried along the Delaware and Lackawaxen Rivers and in the northern townships; presumably quarries could be opened in many other places should demand require.

Several million tons of anthracite have been mined in Clinton Township just east of Forest City, more probably than remains unmined and recoverable.

High-silica sand for the manufacture of glass at Honesdale formerly was obtained from the Pottsville conglomerate on the county line in the Moosic Mountains and from the disintegration of the Cherry Ridge conglomerate along the shore of ponds in Dyberry Township. Probably sand suitable for common glassware can be had in moderate amount at these and other localities.

The entire county is more or less blanketed with glacial deposits. Sand and gravel, therefore, must be abundant. One company is producing these materials at Lake Ariel on the Erie Railroad on a commercial scale. Deposits can be opened at convenient places on demand.

Glacial clays, common over most of the plateau, are suitable for the manufacture of common brick. Possibly the Mauch Chunk red shales west of Waymart could be used. Brick have been made at White Mills and Waymart from the Catskill shales that are so abundant in the county.

Peat humus and sphagnum peat may occur in quantity in some of the numerous bogs.

WESTMORELAND COUNTY

Area 1,025 square miles. Population 303,411

Westmoreland County lies in the center of southwestern Pennsylvania just east of Allegheny County and north of Fayette County. It is mainly in the Pittsburgh Coal Area, but the eastern portion is in the Allegheny Mountains Area. The presence of a large tonnage of coal and its nearness to the industrial center of Pittsburgh has made Westmoreland a highly industrialized county. In 1940 its value of manufactured products was over 200 million dollars, fifth among the counties of the State, and more than seven-eighths of the values were products derived from minerals. The main line of the Pennsylvania Railroad crosses the county from east to west and with the Baltimore & Ohio and other railroads, U. S. Routes 22 and 30, and 923 miles of improved State highways, the county has abundant transportation facilities. The Allegheny and Monongahela Rivers give direct water transportation to the markets of the world.

Topography. On the east the county extends to the crest of Laurel Hill, altitude 2,900 feet. At the northwest, it borders on the Allegheny River at just above 700 feet. Chestnut Ridge crosses east of the center of the county, rising to 2,100 feet. The Ligonier Valley between Chestnut Ridge and Laurel Hill has hilltops at 1,600 feet, rising to 1,700 feet near the mountains. West of Chestnut Ridge, the hilltops are below 1,300 feet, except where the Fayette and Grapeville anticlines bring up the harder underlying rocks to make low, broad ridges, reaching 1,400 feet. Though the hilltops of any area rise to just about the same height, giving the uplands a very flat aspect, an intricate drainage system cuts the surface up into a complex pattern of hills and valleys. The valleys are 100 to 300 feet deep and narrow; the hilltops broad, though seldom level.

Rocks. The top of the hills in the Irwin basin contain about 140 feet of the Washington group, including the Washington coal and Calvin Run limestone. The Monongahela group is 380 feet thick, with the Pittsburgh coal at its base, a good body of Redstone, and very little Uniontown and Waynesburg coals, considerable Benwood limestone, and lenses of the Fishpot and Waynesburg limestones. The Conemaugh group is from 660 to 700 feet, thickening toward the east, with several thin coals and limestones, none having any large commercial value. The sandstones and shales have local value for building purposes. The Allegheny group, averaging 285 feet thick, contains the thick and thin Upper Freeport coal, the Lower Kittanning coal, and other coals that are locally mineable. Locally the Upper Freeport limestone is thick and mineable. The Vanport limestone is reported in wells and is probably present under a small part of the northern end of the county. The Pottsville series includes the Mercer coals and clays, the Homewood and Connoquenessing sandstones. The Mauch Chunk shale 30 to 140 feet thick includes the Greenbrier limestone 4 feet thick. It probably underlies all of the county. The Loyalhanna limestone 60 feet thick is brought up in the Laurel Hill and Chestnut Ridge anticlines and is exposed in the water gaps on the principal streams. The Pocono is exposed in the same gaps and widely on the crest of Laurel Hill and in small areas on Chestnut Ridge. Several hundred feet of Devonian is exposed in Laurel Hill where cut by Conemaugh River.

Mineral resources. Coal. Coal is the outstanding mineral resource. The bulk of the mining at present is on the Pittsburgh and thick Upper Freeport coals. Of 106 commercial mines operating in the county in one year, 72 were on the Pittsburgh coal, 26 on the Upper Freeport, and 7 on the Redstone, Upper Kittanning, and Lower Kittanning together. The Pittsburgh coal is from 5 to 8 feet of mineable coal in three basins: the Latrobe-Mount Pleasant on the east, the Greensburg in the center, and the Irwin basin on the west. The small areas in the Ligonier basin are nearly mined out, and in the Greensburg and Irwin basins the coal is approaching exhaustion. Between these basins the surface rocks are the Conemaugh group. The Allegheny group crops out only along the lower flanks of Chestnut Ridge and the western flank of Laurel Hill, and along Allegheny, Kiskiminetas, and Conemaugh Rivers. The Upper Freeport is the most important coal in the Allegheny in this county and mined at numerous places. It is 7 feet thick and mined extensively in Derry, Fairfield, Ligonier, and Lower Burrell Townships. Such information as is available indicates that with the exhaustion of the Pittsburgh and Upper Freeport coals, the other coals in the Allegheny group may have large economic value. The Middle Kittanning appears to be thin, but workable in much of the western part of the county. The Lower Kittanning appears to have some value in the eastern townships, but is deep under cover west of Chestnut Ridge. The Redstone and

Waynesburg coals present stripping possibilities where under shallow cover. The Waynesburg has a maximum thickness of 5 feet, but as usual contains thick partings in addition to being high in ash and sulphur. The Redstone is usually thin, but locally is more than 4 feet thick.

The original deposits of more than 7 billion tons of coal in six beds in this county are estimated to have been reduced 1½ billion tons by coal mined out or lost. Nearly all of this has been from the Pittsburgh bed. The coal still available is principally in the Upper Freeport bed. It is estimated that 1½ billion tons of coal over 3 feet thick remain in the county, 840 million between 2 and 3 feet thick, and over a billion tons of coal under 2 feet thick recoverable in the distant future.

Natural gas. No oil fields have yet been discovered in the county though a little oil is obtained from gas wells. The Murraysville and other gas pools in the northwest corner of the county have produced very large volumes of gas in the past. Farther east, a pool on the Grapeville anticline has produced a large volume of gas; other pools occur on the Fayette anticline. The most prolific sand has been the Murraysville or the Berea, 100 feet or more thick. The Hundred-foot sand under it has also been a large producer. The underlying sands down to the Elizabeth are productive in places. Some gas has also been gotten in the Speechley and Speechley Stray sands in the Grapeville gas pool and some has been obtained from the Tiona sand. A few holes have been drilled to and through the Oriskany sand. Of three wells drilled at McCance on Chestnut Ridge anticline on Loyalhanna Creek, one got half a million cubic feet of gas in the Oriskany, another got gas from a sand in the Upper Silurian. Other wells to the Oriskany sand, including some on Laurel Hill in the northeast corner of the county, have failed to get gas though one of them was drilled to 9,024 feet. The others did not get enough gas to pay development costs.

Clay. The Upper Freeport (Bolivar) clay has proved of value and has been mined at several places for making fire brick. Other beds to be looked for are under the Lower Kittanning and Mercer coals. Mercer clay at Kingston is 8 feet thick, but is a little high in iron. The mining of the Pittsburgh bed has delayed the opening of mines on the other coal beds and this in turn has delayed the discovery of clay beds of value. There is no known reason why valuable beds of clay should not be found when systematically sought. The "main clay" of the Pittsburgh coal has been used locally for refractory ware of certain types. Shales of the Conemaugh and Monongahela groups are being used at New Kensington, Jeanette, between Irwin and Penn, and at Huffs. These shales are abundant and suitable for making paving brick, face, and common brick.

Sandstone. Sandstones are abundant in the county. The Mahoning sandstone was extensively quarried for building locks on the old canal and more recently it has been quarried near Tunnelton for large-sized stone for construction work. In future years there is likely to be a greater demand for stone for construction purposes. The Mahoning and Homewood should be able to meet that demand. Many buildings in the county show what can be done with the local stone. Near Derry the Homewood sandstone has been crushed for glass sand. Silica sand could be produced extensively as this sandstone crops out for many miles on Chestnut Ridge and Laurel Hill.

Sand and gravel. Sand and gravel can be dredged from the river bottoms or dug on the terraces. The river gravels are fresher. The terraces have greater quantities but the upper part is likely to be decomposed and not useable. These deposits are used mainly for sand.

Limestone. The Loyalhanna limestone is exposed only in Chestnut Ridge and Laurel Hill. The best exposures are in the gorges where Conemaugh River and Loyalhanna Creek cut through these ridges. This limestone is 40 to 70 feet thick and about 50 percent silica. A quarry at Long Bridge, near McCance, is about half a mile long. Its annual capacity is about 100,000 tons of crushed stone. Another huge quarry is near Blairsville Intersection. The supply of this rock is inexhaustible. The Greenbrier limestone crops out along the sides of Chestnut Ridge and Laurel Hill and has been quarried in a small way, in many places to burn for agricultural lime. The Johnstown and Lower Freeport limestones are of little importance. The Upper Freeport limestone has been quarried extensively in the past. It is irregular in thickness, usually 3 to 5 feet, but reported to be 10 feet thick in some places. At the old quarries on Conemaugh River the limestone showed over 90 percent calcium carbonate. The Roaring Run anticline brings the Vanport limestone above water level in Bell Township, where it is 7½ feet thick. This limestone has not been developed in the county and its value is unknown. The other limestones are thin and impure. The Colvin Run and Mount Morris limestones each show about 75 percent calcium carbonate, 8 to 10 percent silica. The Benwood limestone ranges from 55 to 85 percent calcium carbonate with 6 to 16 percent silica and from 2 to

20 percent magnesium carbonate. The Benwood is from 50 to 75 feet thick and is suitable for ag-lime, as are similar limestones at several other horizons.

Salt. An unfailing supply of salt water derived from wells mostly less than 1,000 feet deep was the source of the salt industry on Conemaugh River for several decades in the nineteenth century. Because the brine was weak, the evaporation process took much time and fuel. This brine may eventually be wanted.

WYOMING COUNTY

Area 396 square miles. Population 16,702

Wyoming is one of the northeastern counties, situated 40 miles west of Delaware River and 25 miles south of New York State. The population is largely rural. Tunkhannock, the largest borough, has 2,161 people, and Nicholson, next largest, has 1,012. Susquehanna River crosses the county diagonally in a crooked course and deeply intrenched below the upland. Railroads follow the river, and cut across the northeast and southwest corners. The Roosevelt Highway (U. S. 6), the Lackawanna Trail (U. S. 11), and other important highways traverse the county.

Southwest of the Susquehanna the surface rises rapidly to the high plateau of North Mountain, lying 2,100 feet above sea level and broken only by two deep gorges. This rugged, forested plateau is one of the wildest parts of the State. Northeast of the river the surface is rounded hills with rather gentle slopes, except along the larger streams. Few of the hills rise to more than 1,200 feet above sea level.

Most of the county is covered by glacial drift. Thick deposits of glacial outwash fill old stream channels or are exposed in terraces. The rock formations range from Chemung to Pottsville. The Pottsville formation, Mauch Chunk shale, and Pocono sandstone occur only as cap rocks in North Mountain and outliers in the southwest part of the county. The Chemung formation is at the surface only in the northwest corner. The remainder and greater part of the county is underlain by rocks of the Catskill group.

In general, the rocks are practically horizontal, as there are no major folds. Minor anticlines and synclines trend northeast and dips to not exceed 6°.

MINERAL RESOURCES

Flagstone and bank sand and gravel are the principal mineral products; coal and shale are present but not now used.

It was well said 60 years ago that all reports of gold, silver, copper, and tin in the county "must be explained either by tradition, superstition, or fraud. As valuable ores in any shape, they are everywhere and entirely wanting, and every dollar spent in their search will be wasted." The same is true of lead and zinc.

Coal. In the Bernice syncline southwest of Forkston in the west side of the county, a bed of coal about three feet thick was mined for several years for local use. It is "low-volatile" but occurs in a wilderness country on top of Dutch Mountain under massive conglomerate. Although this coal bed is presumed to underlie a considerable area, data are insufficient for computing reserves.

Shale. Soft red shales between Lovelton and Nicholson might be used in making building brick and tile, but much of the Catskill group is sandy, and there seems to be little shale suitable and available for brick making in the county.

Clay. Glacial clay and terrace clay are available along the Susquehanna south of Tunkhannock and might be used for small brick and tile plants. None of these clays is now worked but they are plastic and although not in large deposits they might be used in making common brick, drain tile, flower pots, and some kinds of pottery.

Flagstone. Stone quarrying has been practically the only mineral industry in Wyoming County for half a century. Flagstone is the principal product, but building stone, sills, and curbstone may be produced from the same beds. The quarries near Skinners Eddy, Laceyville, Black Walnut, and Meshoppen in the northwest corner of the county are in Chemung rocks, and those near Tunkhannock and Nicholson are in Catskill rocks. Quarry sites are in the bluffs along the river and in the bottoms of ravines close to the river. They are on the north side of the river because the railroad is on that side. Other quarries could be opened on the south side.

The stone suitable for flagging is called bluestone, although some of it is greenish gray and some is faintly purple. At first used for sidewalks, the demand in recent years has been for floors in public buildings, libraries, museums, churches, and colleges. Flagstones in different colors may be cut in various shapes and laid in patterns, and the surface may be natural split or honed.

Sand and gravel. Deposits of glacial drift and outwash on terraces along Susquehanna River yield sand and gravel for general building purposes. Bank sand and gravel must be of good quality, not many miles from a market, and close to a railroad or good highway to have commercial value. Such deposits near Falls and Noxen have been worked.

YORK COUNTY

Area 914 square miles. Population 178,022

York County borders on Maryland east of Adams County. Its eastern boundary is the Susquehanna River. Except for a narrow zone on the northern edge of the county in the Kittatinny Valley and a few square miles near Dillsburg in the South Mountain (Appalachian Mountain Area), all the northern part of the county is in the Triassic area. All the southeastern part of the county is in the Piedmont Highland, except a narrow belt of Piedmont Lowland from Wrightsville past York to Hanover. North of this strip are two small irregular uplands of Piedmont rocks, Pigeon Hills and Hellam Hills.

In York County manufacturing is the leading industry in value of products, agriculture is second, and mineral production is comparatively minor. Railroads, U. S. Routes 30 and 111, and 993 miles of improved State highways furnish transportation.

Topography. The southern part of the county is typically dissected Piedmont Upland, the sub-level hilltops rising from 500 feet in the southeastern corner to 800 or 1,000 feet overlooking the Piedmont Lowland to the north. The Lowland lies mostly between 250 and 700 feet above sea level, and presents small areas of flat land with much rolling or hilly land due to the complex structure beneath. The Hellam Hills and Pigeon Hills rise 300 to 600 feet above the surrounding area and culminate at 1,040 and 1,240 feet, respectively. The Triassic area consists of broad, gently rolling upland mainly about 480 feet in altitude near the Susquehanna and rising toward the southwest to 620 feet. Conewago Mountains, sandstone hills, rise to 1,040 feet, and trap hills with seep sides rise to 1,200 feet and more. The high points of South Mountain lie west of York County.

Rocks. The rocks comprise the pre-Cambrian crystalline rocks of both igneous and sedimentary origin overlain by lower Paleozoic sedimentary rocks, and Triassic rocks, both sedimentary and igneous.

The rocks in the southern half of the county are mostly crystalline schists of the Wissahickon formation, in which are folded long narrow bands of "greenstone", slate and quartzite, all of pre-Cambrian ? age. These are overlain by Hellam conglomerate and Chickies slate 350 to 1,000 feet thick, Harpers phyllite 800 feet, Antietam quartzite 100-200 feet, Vintage dolomite 800 feet, Kinzers formation 200 feet, and Ledger dolomite 1,000 feet.

Younger than these and possibly of Ordovician age is the Conestoga limestone 500 feet thick, in the York-Hanover Valley.

The northwest part of the county is largely underlain by the New Oxford formation 6,000 feet thick and the Gettysburg shale and sandstone 9,000 to 18,000 feet, of Triassic age, intruded by great masses of diabase.

In South Mountain near Dillsburg on the northwest border of the county are approximately 2,000 feet of Lower Cambrian quartzites, Tomstown dolomite 1,000 feet, and along Yellow Breeches Creek Waynesboro formation 750 feet. At Williams Grove is a small area of Elbrook limestone; farther east along the creek, a narrow belt of Beekmantown limestone, and Leesport limestone 80 feet; and Martinsburg shale 500 feet, in two loops of the creek. The pre-Triassic rocks are complexly faulted and folded. Small remnants of high-level river gravels occur near the Susquehanna River and Conewago Creek.

Mineral Resources. High-grade limestone in the middle of the Kinzers formation between York and Thomasville is used for portland cement, flux, in glass making, and burned for lime. Less pure limestone and dolomite are quarried for agricultural lime and crushed stone. The quantity is abundant. Some of this rock is white marble carrying 98 percent calcium carbonate. The Tomstown (Ledger) dolomite is suitable for furnace bottoms, plaster, agriculture, and chemical industries. The Vintage dolomite is quarried at Wrightsville and elsewhere along its extensive outcrop for road metal and concrete.

Peach Bottom slate has long been quarried in the southeast corner of the county between Delta and Peach Bottom. High-grade roofing slate remains in the old pits and endless amounts of slate suitable for grinding into granules and dust are available.

Magnetic iron ore near Dillsburg and Grantham has been largely mined out; some ore may remain. Limonite at the contact of the Antietam quartzite and Tomstown (Vintage) dolomite has been extensively mined on the south side of Hellam Hills, Pigeon Hills, and South Mountain. Some iron ore is thought to remain at this and some other horizons.

Clay from weathered limestone, schist, and schistose quartzite is abundant and used for brick, floor tile, and pottery. It is suitable for art tile, hollow tile, and flower pots. White clay suitable for filler in paper and paint occurs in South Mountain but its abundance is yet to be determined. Soft shale in the Triassic area is abundant and could be used for building brick and tile. Building sand is derived from the weathering of the quartzite or the distinegration of the sandy Conestoga limestone. Two quarries in the gorge of Codorus Creek north of York produce sand. The

Chickies and the Antietam quartzites and some of the Triassic sandstones have been used for building purposes. The quartzites have largely replaced the brown Triassic sandstone in favor. The quantity is large. Limestone here, as a rule, does not break favorably for building stone because of pressure strains. The diabase or trap rock, baked shales, limestones, and other materials furnish abundant stone for crushing.

Coal is dredged from the Susquehanna River, chiefly in the slack water above the Holtwood dam. It is granules of anthracite brought down from the anthracite fields by high stages of the river.

REFERENCES

The principal sources of information on mineral resources are the reports of the Pennsylvania Second Geological Survey, the Topographic and Geologic Survey Commission, Topographic and Geologic Survey (4th Series), and the U. S. Geological Survey. The Second Survey reports are designated by letters and figures. In the following table under Comm. Survey, R 10 means Report No. 10. Under 4th Series, A is for Atlas, C for County, and M for Mineral Resource. In the last column, F indicates folios, and B, Bulletins. This table does not include the present Survey 4th Series bulletins M 15, 20 and 23 on Building Stones, Limestones, and Clay and Shale, respectively, because they contain data on all or most of the counties.

County	*2d Survey*	*Comm. Survey*	*4th Series*	*U. S. Geological Survey*
Adams	C	....	C 1, M 16	F 225
Allegheny	Q	R 1	A 27, M 6, 17	F 176, B 456
Armstrong	H 5	....	A 36, M 6, 10, 17	F 115, 123, 125, 178, B 256, 279
Beaver	Q	....	A 5, M 6, 17	F 134, 176, B 273, 286
Bedford	T 2	R 10, 12	M 3, 6, 10, P.R. 128	F 133
Berks	D 3, pt. II	R 6	M 3, 16	B 891
Blair	T	R 12	A 96, M 3, 5, 6	F 133
Bradford	G	....	M 6, B 108	......
Bucks	C 6, DD	....	M 5	F 167, B 828, 920
Butler	Q, QQ, V	R 1	A 36, M 6, 17, P.R. 122	F 115, 176, 178, B 279, 454, 829, 873
Cambria	HH	....	M 6, 10	F 133, 174, 189, B 447
Cameron	RR	....	M 6, 10, P.R. 109	......
Carbon	....	R 12	M 16	......
Centre	T 4	R 12	A 96, M 3, 5, 6, 10	B 855
Chester	C 4	R 6	M 5, 13, 14	F 162, 223, B 891
Clarion	....	R 3	A 54, M 6, 10, 25	F 178, B 454
Clearfield	H 7	R 12	A 65, 75, M 6, 10	......
Clinton	G 4	....	M 3, 6, 10	......
Columbia	G 7	....	......	......
Crawford	Q 4	....	M 6, 22	......
Cumberland	M 3, 1886, pt. 4	....	P.R. 128	B 315
Dauphin	....	....	......	B 840
Delaware	C 5, 1885, pt. II	....	M 13	F 162
Elk	RR	R 12	M 6, 10, P.R. 110	......
Erie	Q 4	....	......	......
Fayette	KK, KKK	R 12	C 26, M 6, 10, 17	F 82, 94
Forest	RR	R 12	M 6, P.R. 118	......
Franklin	M 3	....	M 3, P.R. 128	F 170
Fulton	T 2	R 10	M 3, 6	F 170
Greene	K	....	C 30, M 6, 17	F 82, 121, 146, B 304
Huntingdon	F, T 3	R 10, 12	A 96, M 3, 6, 10	......
Indiana	HHHH	....	A 65, M 6, 10, 17	F 102, 110, 123, 189, B 256
Jefferson	H, H6	....	A 54, 65, M 6, 10, P.R. 121	......
Juniata	F 3, M 3	....	M 3	......
Lackawanna	G 7	....	......	......
Lancaster	CCC	....	A 168, 178, M 3, 5, 16	B 134, 725, 799, 840, 891
Lawrence	QQ	....	A 5, M 6, 17	B 873
Lebanon	1885, 1886, pt. IV	....	A 168, M 3, 16	B 359, 840
Lehigh	D, DD, D 3	....	C 39, A 206, M 5, 16	......
Luzerne	G 7	....	M 10	......
Lycoming	GG	....	M 6	......

County	*2d Survey*	*Comm. Survey*	*4th Series*	*U. S. Geological Survey*
McKean	R	....	M 6, 21, P.R. 125	......
Mercer	QQQ	....	M 6	......
Mifflin	F, F 3	R 12	M 3	......
Monroe	G 6	R 12	......	......
Montgomery	C 6	....	M 3	F 162, B 828, 891
Montour	G 7	....	M 3, 11	......
Northampton	D 3	R 5	A 206, C 48, M 16	B 920
Northumberland	G 7	....	M 11	......
Perry	F 2	....	......	......
Philadelphia	C 6	....	......	F 162
Pike	G 6	....	......	......
Potter	GGG	....	M 3, 6, P.R .106	......
Schuylkill	....	....	......	......
Snyder	F, F 3	....	M 3	......
Somerset	H 3	....	M 6, 10	......
Sullivan	GG	....	......	......
Susquehanna	G 5	....	......	......
Tioga	G	....	M 6, 10, P.R. 107	F 93
Union	F 3	....	......	......
Venango	I	R 12	M 6, 22, 24, 25, P.R. 122	B 454
Warren	I 4	R 12	M 6, 22	F 172
Washington	K	....	M 6, 17	F 144, 177, 180 B 300, 318, 456
Wayne	G 5	....	......	......
Westmoreland	KK, KKK	R 12	A 36, 37, M 6, 10, 17	F 94, 110, 123, B 256
Wyoming	G 7	....	M 10	......
York	C, CC	....	C 67, M 16	B 799, 840

Publications of the Pennsylvania Second Geological Survey (1874-1887) and of the Topographic and Geologic Survey Commission (1899-1914) are out of print, but are on file in many public libraries throughout the State and in libraries of larger cities in other states. Reports of the present Survey (1919-) and of the U. S. Geological Survey also are on file in many libraries.

A list of publications of the Pennsylvania Topographic and Geologic Survey, 4th Series, and of the U. S. Geological Survey referred to in the foregoing table can be obtained on application to the State Geologist, Department of Internal Affairs, Harrisburg, Pa. The list covers more than 8 octavo pages and is too long to publish here.

PART III

TECHNOLOGY AND TRENDS IN THE MINERAL INDUSTRIES

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Part I of this publication deals with a statistical record of past accomplishment. Part II indicates the reserves still available for future use. Part III deals with the utilization of this material and the means by which it may be made of service to industry.

Acknowledgment: All reproductions of paintings in this volume are published by the courtesy of Dean Steidle. Originals may be seen in the Mineral Industries Art Gallery at State College.

TECHNOLOGY AND MINERAL RESOURCES

FEW minerals are serviceable to mankind in their natural state. They must be freed from associated worthless materials, reduced to metallic form, or have their physical or chemical properties altered to produce desired results. The earth sciences, mineral engineering and technology deal with these processes. Technology includes the application of all branches of science and engineering to the exploitation and development of mineral resources for the benefit of mankind. It begins with the finding of the ore and includes all processes and procedures necessary to recover and convert the ore into a raw material useful for manufacture into articles of commerce.

The present productive capacity of Pennsylvania, now strained to its limits by the demands of war, is the result of the application of research to technological problems. We have been able to produce an overwhelming weight of the munitions of war not only because we have the raw materials but chiefly because we have developed the necessary skills and processes for making useful products from them and from imported minerals.

The products of the mines, unlike the products of farms, forests, and waters cannot be replaced; when once used up or destroyed they are gone. The history of the exploitation of mineral resources follows a similar pattern the world over. Following the discovery of the deposit there is the initial period of development when the best and most easily recovered material is taken. As this "cream of the crop" is exhausted, the miner must turn to the less accessible or poorer grades for his product. He is, therefore, constantly faced with natural conditions of increasing difficulty and is in a continuous battle with increasing costs. He must have the ammunition furnished by intelligent research in mineral technology if he is to win this battle. The only alternative, as in any battle, is to give ground, and that means loss of employment, ghost towns, and economic instability.

Mineral economics, therefore, is the record of a battle between the growing difficulties of nature on the one hand, and discovery, transport, and technology on the other. It has been evident for many years to those who would read the record that Pennsylvania was rapidly facing the penalties of pioneering. The war, by accelerating the drain on mineral resources, has greatly hastened the day of reckoning. The losses due to the war must be compensated for as much as possible in the post-war years. We must continue to provide the raw materials upon which so much of the industrial and economic life of the Commonwealth depends, and we must increase the efficiency of all operations so that industry will be able to pay the staggering load of taxation that is inevitable.

Discovery, transport, and technology are still the factors in favor of man in his battle against the advancing costs of nature. An inventory must be made of our resources, using the new techniques of discovery; transport must be used to bring raw materials to Pennsylvania for processing. And, finally, the heavy guns of technology must be brought to bear on the problem so that Pennsylvania may retain its supremacy not only as a producer and processor of minerals but as a developer of new arts, skills, processes, and techniques. There is only one way to accomplish this and that is by a greatly expanded program of education and research in mineral technology.

Various attempts have been made to define research. It is increasingly recognized that it includes all investigation diligently carried on to increase and broaden the base of knowledge. Attempts to make a distinction between research in pure theory and practical application are of little importance. Indeed, it has been a fact frequently repeated in the past that the results of the most theoretical investigation of one generation become the basis of ordinary industry in the next. The edifice of science resembles a great building. Contributions to its erection have been made by many workers and it is the result of the cooperative effort of an army of little-known men. Frequently the material developed by one worker is used by another. Some of the greatest contributions to the welfare of man have been the result of accidental observations and not the product of the investigation immediately in hand.

There are no white rabbits to be taken out of the research hat; profitable results are the result of careful planning and long drawn out and painstaking work. The application of insurance to all types of risk has been one of the most conspicuous developments of the past few years. The public has become conscious of this through the almost universal distribution of insurance of hazards related to automobile operation and the adoption of social security under government control. A properly conceived program of research operates in exactly the same manner. A small portion of current earnings is laid aside and invested in the exploration of scientific principles and the development of techniques by which industry in the future can be assured of existence. Research conducted by the universities, industry, and the Federal government is now properly considered to be a national resource.*

The production figures have indicated the vast increase in mineral production in Pennsylvania. The needs of the future cannot be determined accurately. However, with an increasing use of minerals by society and a population still expanding, it is apparent that consumption in the next few decades will be substantially above that of the past. In addition to the well-established uses of mineral products, it is realized that the ultimate possibilities in placing minerals at the service of man have not been approached. Plastics and textiles of mineral origin indicate what may be done.

The problem of technology, therefore, is three-fold. First, economic processes must be developed to obtain useful minerals from lower grade reserves; second, costs of production and manufacture must be kept low by means of economic and efficient operations; and finally, new processes and products must be developed to utilize all the possibilities of our mineral resources.

To date depletion of resources is a local problem and it is reassuring to note from the information in preceding chapters that there are large mineral reserves remaining in Pennsylvania, adequate for many years to come. However, the future prosperity of Pennsylvania is dependent upon the intelligent and economic utilization of this mineral heritage.

In Pennsylvania certain problems are more conspicuous than others. In general, it may be stated that every increase in the efficiency of the finding, extracting, and processing of minerals must be promoted. The knowledge of the fundamental geology of the State must be expanded and the industrial possibilities of all minerals inventoried. Mining costs must be reduced to improve the competitive position of our fuels. Safety in all operations must be assured. Uses must be found for the large tonnages of materials known to exist but for which little or no market is present. Methods must be devised for the treatment of low grade ores or depleted oil fields. Industrial wastes must be eliminated. Any mineral deposit in Pennsylvania has great place value, that is, it is located in a densely populated area containing an immediate market and the necessary fuels and skilled labor to make it useful. Men must be trained, including the technical graduate and the worker skilled in the operation of mechanical equipment.

The trends and possibilities for development of the important mineral resources are discussed separately in the succeeding pages.

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* Research—A National Resource. I. Relation of the Federal Government to Research. December 1938. National Resources Committee.

Research—A National Resource. II. Industrial Research. December 1940. National Resources Planning Board.

TRENDS IN THE PENNSYLVANIA COAL INDUSTRY

IN PREPARING the information presented in this discussion we wish to acknowledge the assistance given us by the Bureau of Mines and Solid Fuels Administration, United States Department of the Interior, and by the publishers of Mechanization and Mech-annual. Data for the war years were not included, since the trends induced by the war do not show the trends likely to be encountered in the post-war years. Certain information presented is not available for the years other than those stated.

ANTHRACITE

Mining

The Pennsylvania anthracite industry is unique in the coal mining industry of the United States in that almost all conceivable varieties of natural conditions are encountered. Beds as thick as 100 feet may be mined at the same operation where beds as thin as 22 inches are mined. The coal beds may range in pitch from horizontal to vertical.

Mining has become increasingly difficult and yet

Drift Mine Mouth
by Lawrence Whitaker

TABLE 1. ANTHRACITE MINING TRENDS

	1928	1932	1936	1940
Total production, millions of tons	75	47	54	48
Number of men employed, thousands	160	115	98	90
Indicated tons per man day	2.1	2.5	2.7	3.0
Underground scraper mined, thousands of tons	..	2600	2960	2980
Underground conveyors, thousands of tons	..	2780	7860	9340
Strip mined, thousands of tons	..	..	6300	6352
Produced by dredging, thousands of tons	..	..	547	943
Produced from culm banks, thousands of tons	..	..	3130	2400

average production per man day is slowly increasing, despite the increasing difficulties of production during the past decade. This is on account of mechanization of operations, both underground and strip. Trends in production are shown in Table 1.

Preparation

Anthracite largely enters the domestic market where size, cleanliness, and appearance are all important. All anthracite is mechanically cleaned and sized. Further, each car shipment is sampled and tested to see that the shipped product conforms to certain minimum standards. Also each car is inspected for appearance. Anthracite specifications are given in Table 2.

Since general practices of anthracite preparation are closely proscribed, modern developments are with methods and equipment rather than with practices. The general trend is toward the development of methods and equipment to clean and recover small sizes previously wasted and to recover coal from refuse material. The recovery of small sizes of coal from breaker wash water became a commercial reality during 1943 with the construction of a froth flotation plant by the Lehigh Navigation Coal Company.

TABLE 2. ANTHRACITE TRADE NAMES, SIZES AND SPECIFICATIONS

Trade name	*Size round-mesh screen. Diameter in inches*		*Maximum percent*				
			Size		*Impurities*		
	Through	*Over*	*Oversize*	*Undersize*	*Slate*	*Bone*	*Ash*
Lump	..	6	(These two sizes made for preparation plant purposes only. They are not standardized.)				
Steamboat	6	4⅜					
Standards adopted by Anthracite Institute—1936.							
Broken	4⅜	3¼	5	15	1.5	2	..
Egg	3¼	2-7/16	5	15	1.5	2	..
Stove	2-7/16	1⅝	5	15	2	3	..
Chestnut	1⅝	13/16	5	15	3	4	..
Pea	13/16	9/16	10	15	5	5	..
Buckwheat No. 1	9/16	5/16	10	15	..	..	15
Rice No. 2	5/16	3/16	10	15	..	..	15
Barley No. 3	3/16	3/32	10	20	..	..	15
Not standardized. Maximum specification of consumers given.							
Anthrafine No. 4	3/32	3/64	..	25	..	..	15
Anthrafine No. 5	3/64	1/64	..	..	..	..	15
Birdseye	Mixture of Rice and Barley.						
Anthrafilt	For filtration purposes. Low ash. Sizes from stove to barley, inclusive, used. Anthrafilt No. 1 is a mixture of sizes; anthrafilt No. 2, barley; No. 3, rice; No. 4, buckwheat; No. 5, pea; No. 6, chestnut; and anthrafilt No. 7 is 2 x 2⅜ inches.						

Marketing, Transportation, Utilization

Pennsylvania anthracite moves principally by rail (approximately 85 percent), by truck (13.5), and by rail and tidewater (1.5) to New York, Pennsylvania, and New England. Some is shipped by rail and some by rail and lake cargo to destinations west of Pennsylvania. A small amount is exported.

The Northern Field accounts for over half of the anthracite mined and shipped to market. Production is shifting to the Middle and Southern Fields.

The geographic flow of anthracite from the producing fields to consuming areas is shown by figure 15 for the year 1940. This year was selected as being representative of the normal geographic flow of anthracite undisturbed by war conditions.

Anthracite is primarily a domestic fuel. The year 1939 was selected as being representative of the peacetime use of anthracite and the use flow diagram of figure 16 constructed. As combustion devices improve, an increasing amount of anthracite enters the industrial market. This is reflected in the gradual improvement of the price structure for the small sizes. Trends in prices, sizes, and realization are given in Table 3.

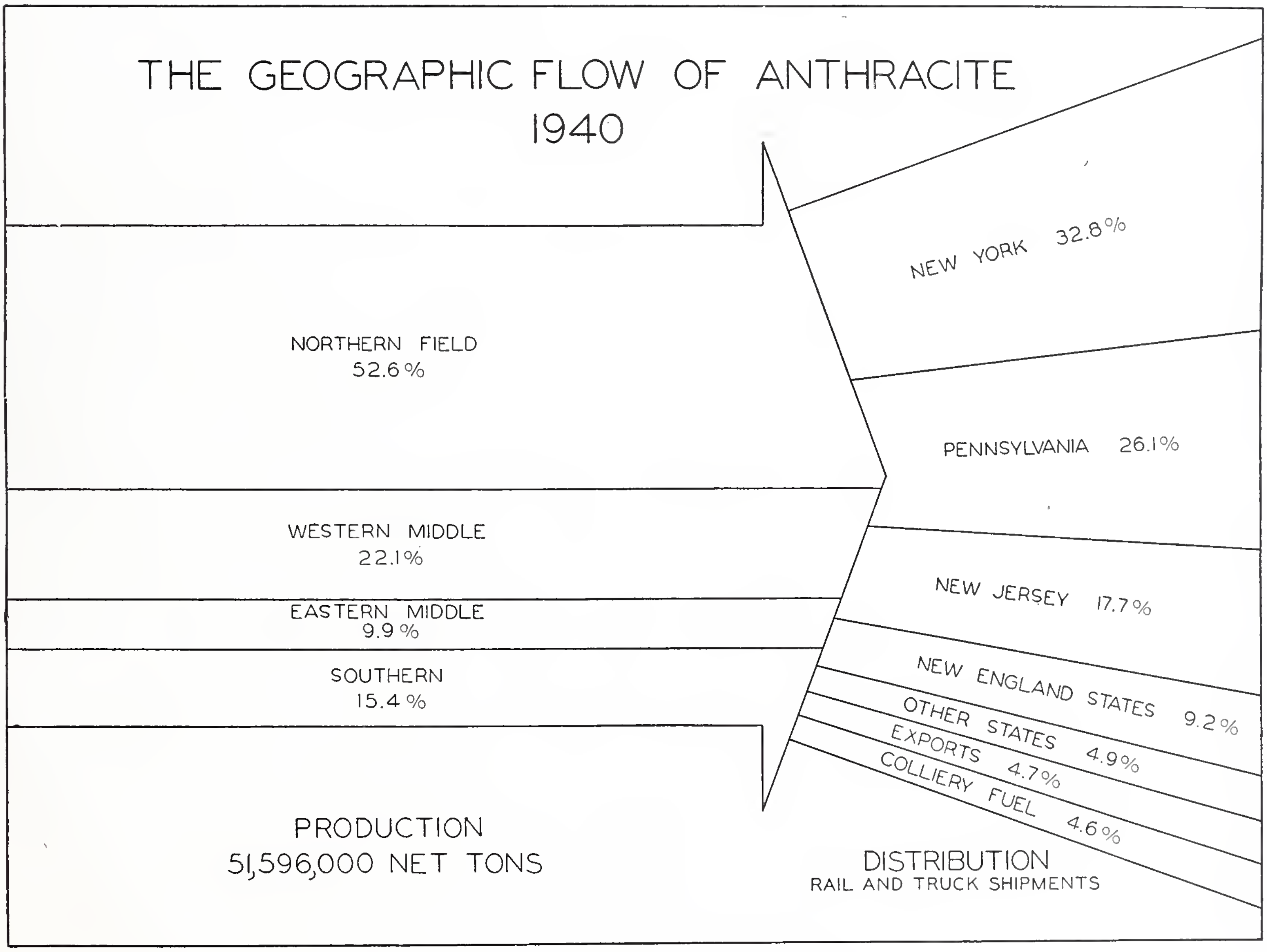


FIGURE 15

Figure 16

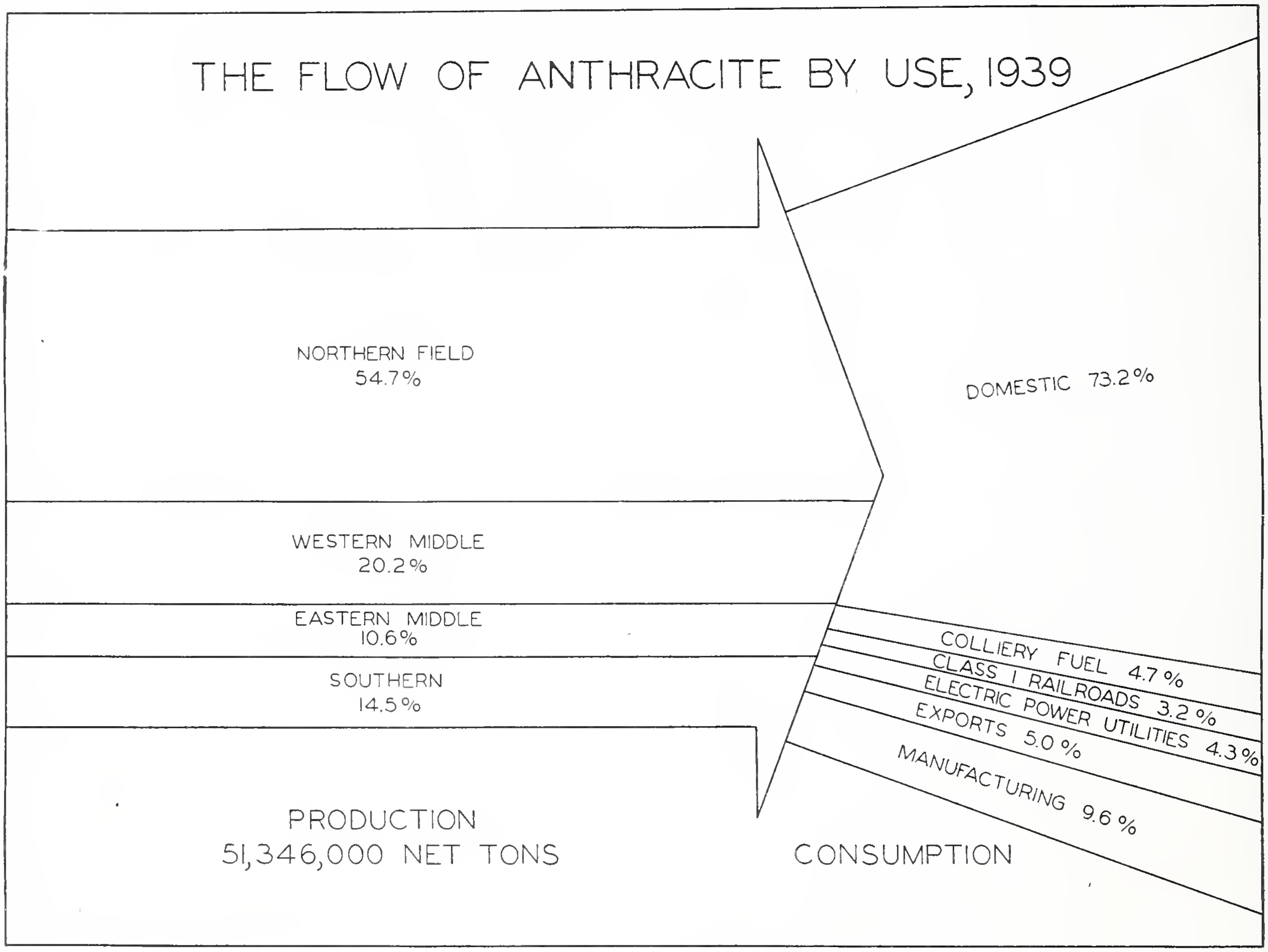


Table 3. ANTHRACITE REALIZATION

Trends in average sales realization per net ton of breaker shipments, by sizes

		1924	1928	1932	1936	1940
Domestic	Lump and broken	....	....	$5.69	$5.05	$5.49
	Egg	....	....	6.17	5.60	5.32
	Stove	$7.80	$7.79	6.53	6.09	5.47
	Chestnut	....	....	6.26	5.91	5.49
	Pea	5.00	4.46	4.55	4.30	4.13
All domestic, weighted average		7.37	7.22	6.09	5.67	5.24
Steam	Buckwheat No. 1	2.63	2.46	2.83	2.91	3.18
	Buckwheat No. 2 (rice)	1.72	1.65	1.52	2.01	2.35
	Buckwheat No. 3 (barley)	....	....	.97	1.23	1.68
	Other, including Buckwheat No. 4	....	....	....	0.68	0.92
All steam, weighted average		2.01	1.89	1.98	2.10	2.41
All sizes, weighted average		5.98	5.70	4.74	4.42	4.27

Trends in sizes—Percentage by sizes in total breaker shipments

		1924	1928	1932	1936	1940
Domestic	Lump and broken	2.7	0.7	0.3	0.3	0.3
	Egg	14.5	11.7	9.1	6.5	4.5
	Stove	22.2	25.6	23.7	21.3	24.1
	Chestnut	26.5	25.4	24.3	26.4	25.9
	Pea	8.3	7.8	9.9	10.4	11.1
All domestic		74.2	71.2	67.3	64.9	65.9

Steam	Buckwheat No. 1	....	13.2	15.5	15.1	14.7
	Buckwheat No. 2 (rice)	....	7.8	8.6	8.4	7.8
	Buckwheat No. 3 (barley)	....	6.8	7.2	8.8	8.8
	Other, including Buckwheat No. 4	....	1.0	1.2	2.8	2.8
All steam		25.8	28.5	32.7	35.1	34.1

Trends in circular prices—Prices per net ton for the month of February

Egg	$8.17	$7.29	$7.35	$6.75	$6.25
Stove	8.17	7.71	7.60	7.40	6.25
Nut	8.17	7.29	7.60	7.00	6.25
Pea	5.89	5.42	5.35	5.00	4.75
Buckwheat No. 1	2.68	2.71	3.25	3.25	3.50
Buckwheat No. 2	2.01	1.88	1.85	2.40	2.75
Buckwheat No. 3	1.34	1.44	1.40	1.55	2.00
Smaller	0.50	....	....	....	1.00

BITUMINOUS COAL

Mining

The bituminous coal fields of Pennsylvania are divided into two districts—District 1 comprising the coal basins in the central and west central part of the State with low and medium volatile coals, and District 2 comprising the western part of the State containing high volatile coals.

A large percentage of the high quality, easily won bituminous coal has been mined. Much of the remaining coal is in thin beds, beds with excessively thick partings, impure coal beds, and beds with bad roof conditions. Despite these unfavorable natural conditions, mechanization of mining operations and improvement of preparation facilities have markedly lowered the cost of producing a ton of coal. This same trend is taking place in neighboring districts so that mine operators are forced to use the utmost in engineering ingenuity to meet competition. Trends in the average cost of producing a ton of coal from mechanized mines for Pennsylvania districts and adjacent districts for the years 1938, 1939, and 1940 are given in Table 4.

A new wage scale was signed in 1941 and since then costs have increased. This increase has been expanded by war-time conditions.

TABLE 4. TOTAL COSTS OF PRODUCING COAL

District	*1938*	*1939*	*1940*
1. Central Pennsylvania	$2.34	$2.22	$2.17
2. Western Pennsylvania	2.29	2.11	2.01
3. Northern West Virginia	1.81	1.74	1.67
4. Ohio	1.92	1.77	1.71
6. Panhandle	1.88	1.67	1.66
7. Southern (low volatile)	2.25	2.10	2.06
8. Southern (high volatile)	2.07	1.97	1.93

Strip mining has increased rapidly under the influence of the war. Bituminous coal strip mine production by counties for 1942 is given in Table 5.

TABLE 5. PENNSYLVANIA STRIP MINE PRODUCTION IN 1942 BITUMINOUS

County	*Net tons*	*County*	*Net tons*
Washington	1,772,301	Clinton	173,783
Clarion	1,713,892	Centre	138,815
Westmoreland	1,306,296	Mercer	134,406
Allegheny	1,208,934	Lawrence	90,039
Fayette	800,453	Tioga	86,492
Clearfield	745,258	Cambria	83,947
Armstrong	471,463	Fulton	78,827
Beaver	418,536	Venango	5,563
Jefferson	380,502	McKean	4,367
Butler	267,238	Lycoming	1,885
Somerset	218,690		
		Total	10,101,681

Central Pennsylvania	4,915,558	½ Fayette, Westmoreland, Armstrong production
Western Pennsylvania	5,186,123	½ Fayette, Westmoreland, Armstrong production

Technologic trends in the effect of mechanization on production, both underground and strip, are given in figures 17-26.

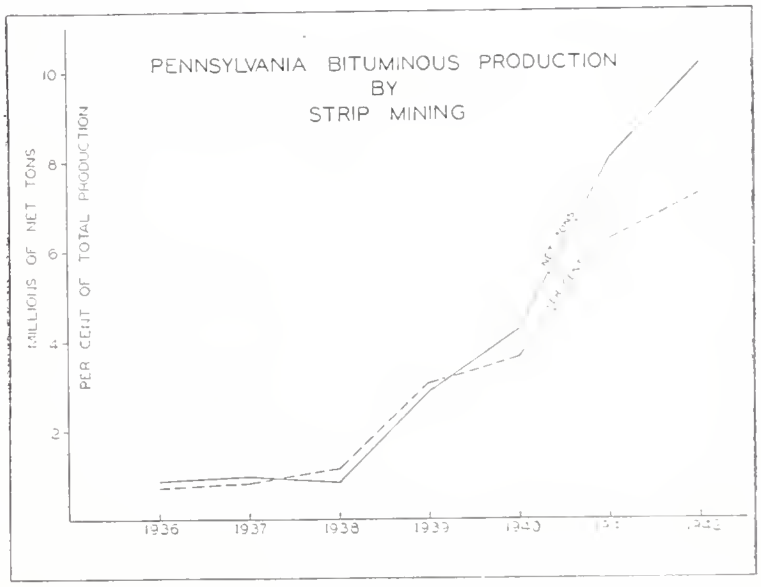


FIGURE 17

On account of the depletion of the thick beds of coal, more and more coal is being mined from thin beds. An appreciable amount of coal from central Pennsylvania is mined from coal beds between two and three feet in thickness. The distribution of the production of Pennsylvania coal for 1939 according to thickness of coal bed is given in Table 6.

TABLE 6. PRODUCTION OF COAL FROM BEDS OF DIFFERENT THICKNESS

	Central Pennsylvania	*Western Pennsylvania*
Plus 8′ 0″	....	8,200,000
7′ 0″–7′ 11″	....	13,700,000
6′ 0″–6′ 11″	250,000	17,800,000
5′ 0″–5′ 11″	3,100,000	10,500,000
4′ 0″–4′ 11″	5,500,000	4,550,000
3′ 0″–3′ 11″	20,800,000	1,760,000
2′ 0″–2′ 11″	3,500,000	740,000

95.6 percent of the coal from western Pennsylvania comes from beds 5 feet thick and more, and only 10.0 percent of central Pennsylvania's production. Further, 62.8 percent of the coal mined in central Pennsylvania is from beds between 3 and 4 feet thick. 10.5 percent of the coal mined in central Pennsylvania is from mines where the coal is less than 3.0 feet thick. The percentage production of coal from thin beds is increasing and since more than half of the available reserve is in these thin beds, future mining must be in these beds. Considerable thought must be given to mechanizing production from these thin seams in order that coal from central Pennsylvania can be mined in competition with bituminous coal from other producing areas.

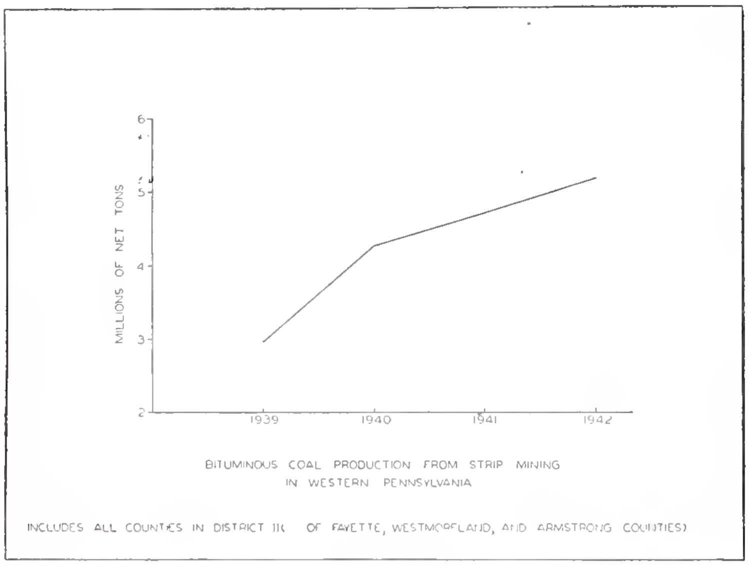


FIGURE 18

The 1939 production of coal in western Pennsylvania was largely from the Pittsburgh bed (79.9%), thick Freeport (12.8%), Upper Freeport (4.5%), with minor amounts from the Lower Freeport, Kittanning, Redstone, Sharon, Sewickley, Cannel, and Brookville coals (2.8%). The 1939 production in central Pennsylvania came from the Lower Kittanning (49.8%), Upper Freeport (20.3%), Lower Freeport (15.4%), Upper Kittanning (11.3%), and miscellaneous beds (3.2%). The 1939 figures are used since at the time of writing, this was the only recent year for which these percentages were immediately available.

Preparation

Bituminous coal mining is characterized by a wide variety of preparation methods and practices. No universal standards exist as to degree of cleanliness, trade names, and sizes as are found in the anthracite industry.

Mechanical preparation developed rapidly during the past decade. This was partly due to more stringent consumer specifications and partly to growth of mechanical underground loading and strip mining. The growth of mechanical cleaning in Pennsylvania parallels that for the nation as a whole as shown in Table 7.

TABLE 7. MECHANICALLY CLEANED PRODUCTION

	1927	*1936*	*1940*
United States, thousands of tons	27,692	61,095	94,700
United States, percent	5.3	13.9	20.9
Pennsylvania, thousands of tons	5,625	21,584	26,700
Pennsylvania, percent	4.2	19.6	23.6

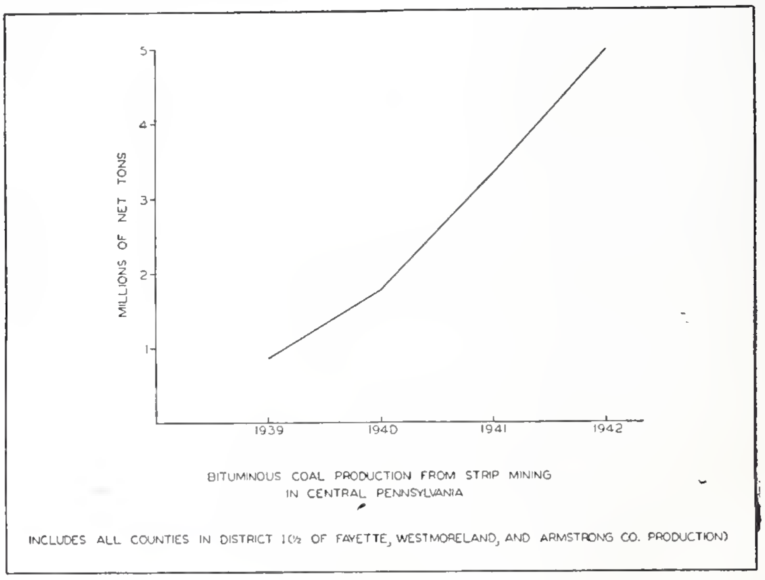


FIGURE 19

Sizes prepared at Pennsylvania bituminous mines are given for rail shipments to Pennsylvania, New York, New Jersey, Delaware, Maryland, and the western part of New England during 1937 in Table 8. This is the only year for which complete figures of the number of sizes and amount of each size shipped are available.

TABLE 8. SIZES PREPARED AT PENNSYLVANIA BITUMINOUS MINES AND SHIPPED BY RAIL TO EASTERN MARKETS, 1937

Size group	*Central Pennsylvania*		*Western Pennsylvania*	
	Size	*Tons*	*Size*	*Tons*
Large lump 4″ and over				
1	6″	16,243	4″	63,646
2	5½″	12,691	5″	1,677
3	(5)	43,081	(4)	66,801
Lump under 4″				
1	½″	112,514	3″	84,303
2	2″	96,872	2″	60,981
3	(14)	432,166	(8)	198,901
Large egg over 6x3″				
1	8x2″	47	6x4″	19,044
2	....	....	....	....
3	(1)	47	(1)	19,044
Egg 6x3″ and smaller				
1	4x2″	41,243	4x2″	133,939
2	6x2½″	22,161	4½x2″	46,342
3	(12)	113,594	(10)	209,827
Egg and nut, under 1½″				
1	4x¾″	6,115	4x1⅛″	34,636
2	5x¾″	5,181	4x1¼″	9,636
3	(6)	15,630	(4)	44,612
Stove, 3″ top size				
1	3x1½″	18,177	3x¾″	25,196
2	2¼x1¼″	8,981	3x1¼″	14,371
3	(9)	49,088	(6)	52,688
Nut, 2″, 1½″ and 1⅜″ top size				
1	2x½″	97,097	2x1¼″	84,430
2	2x¾″	68,364	2x1⅛″	76,997
3	(16)	288,738	(8)	265,504
Pea or stoker, 1¼″ and 1⅛″ top size				
1	1¼x¾″	43,150	1⅛x⅜″	87,901
2	1¼x¼″	30,554	1¼x½″	52,352
3	(6)	79,924	(8)	214,805
Pea or stoker, 1″ and under, top size				
1	1x½″	17,086	1x⅜″	14,857
2	¾x⅜″	16,117	1x⅝″	5,842
3	(8)	44,404	(4)	23,906
Run of mine, and resultants over 2″ top size				
1	Strom *	3,420,469	Strom	748,165
2	Dom rom **	578,989	6″ resul ***	43,513
3	(17)	4,149,805	(7)	871,561
Modified or dedusted screenings, over ½″ top				
1	....	....	1⅛″ mod ****	8,233
2	....	....	1⅛″ mod	5,791
3	....	....	(4)	17,818
Screenings and nut-slack over ½″				
1	¾″	1,669,083	1¼″	427,414
2	2″	1,596,473	¾″	221,050
3	(11)	4,371,097	(8)	993,458
Slack ½″ and smaller				
1	½″	314,485	½″	114,254
2	⅜″	170,015	⅜″	105,119
3	(4)	572,939	(2)	219,373
Middlings, low grade coal and cannel	....	....	....	....
Grand total	(109)	10,160,513	(74)	3,198,298

*** Strom—straight run of mine.**

**** Dom rom—domestic run of mine.**

***** Resultant.**

****** Modified.**

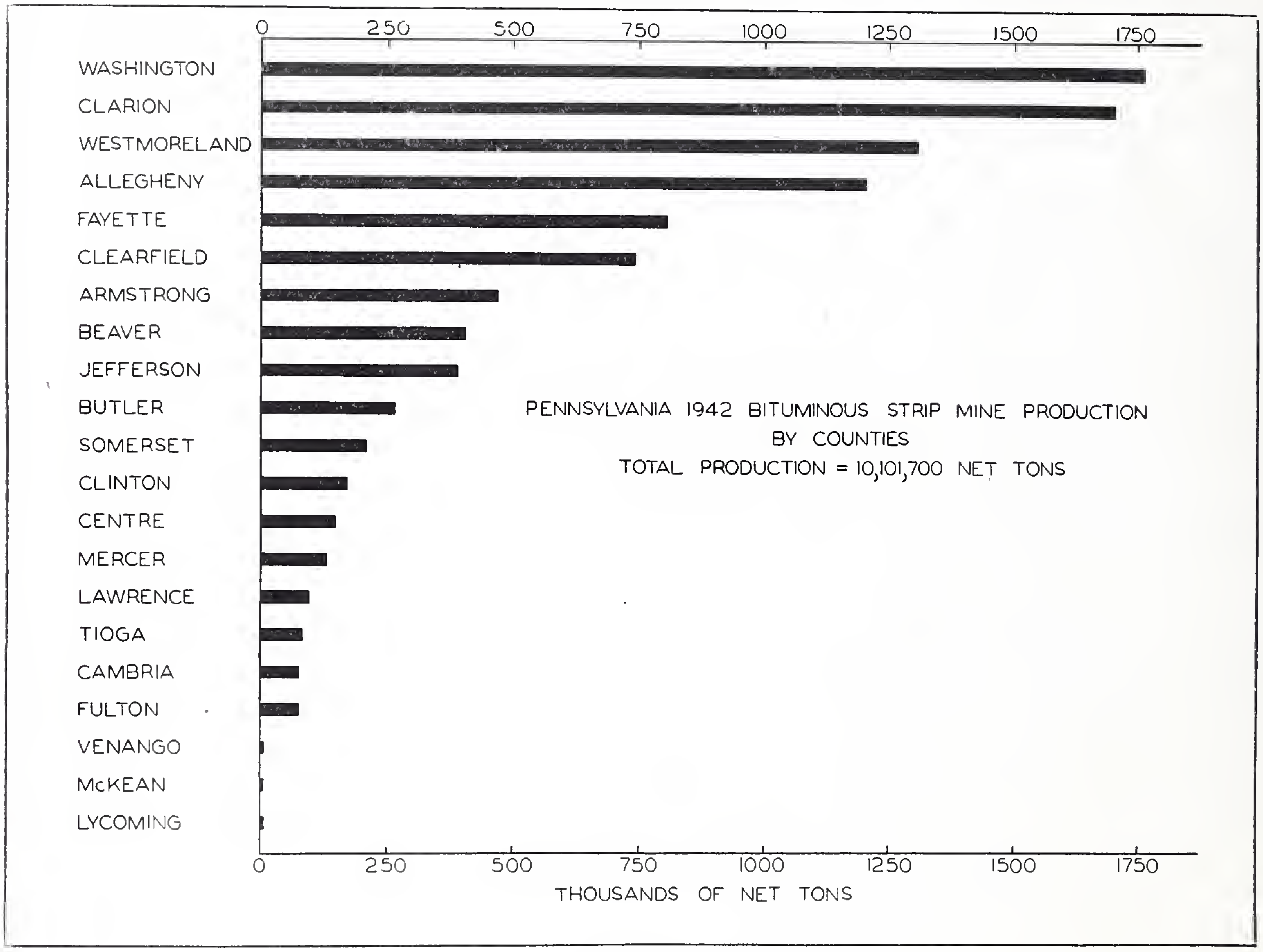


FIGURE 20

Marketing, Transportation, Utilization

In relation to the nation as a whole, Pennsylvania produces approximately one-fourth of the nation's requirements of bituminous coal. Figure 21 gives the relative position of the producing States and the flow of bituminous coal into consuming channels for the year 1940, the last year of available data not disturbed by the war effort.

Approximately half of the bituminous coal produced is used within a relatively short distance of the mines. The other half enters five main channels of flow: 1. rail to New England, 2. tide water movement, 3. lake cargo shipments, 4. westbound rail from the Appalachian producing districts to Mississippi Valley destinations, and 5. rail shipments from mid-continent producing fields to Mississippi Valley manufacturing cities. Pennsylvania coal does not enter number 5. From 50-70 percent of the coal produced in central Pennsylvania moves by rail to destinations in New York, New Jersey, and New England.

Tide-water Loadings. Coal loaded at tide-water during 1940 was distributed to: Bunker fuel 4.0 percent; coastwise to New England States, 35.1 percent; exports, 8.4 percent; and to industrial centers and cities in New York, New Jersey, and various points along Delaware and Chesapeake Bays, 52.5 percent. This coal originated mainly in the low-volatile fields of West Virginia and central Pennsylvania. The Southern Appalachian fields furnish the largest percentage with central Pennsylvania second. See Table 9.

TABLE 9. ORIGINATING FIELDS OF TIDE WATER SHIPMENTS

Originating Field	*Average percentage 1936-1940*
Meyersdale and Cumberland-Piedmont	6.0
Western Pennsylvania and Fairmont	7.4
Central Pennsylvania	23.4
Southern Appalachian: High Volatile	14.3
Southern Appalachian: Low Volatile	48.9
	100.0

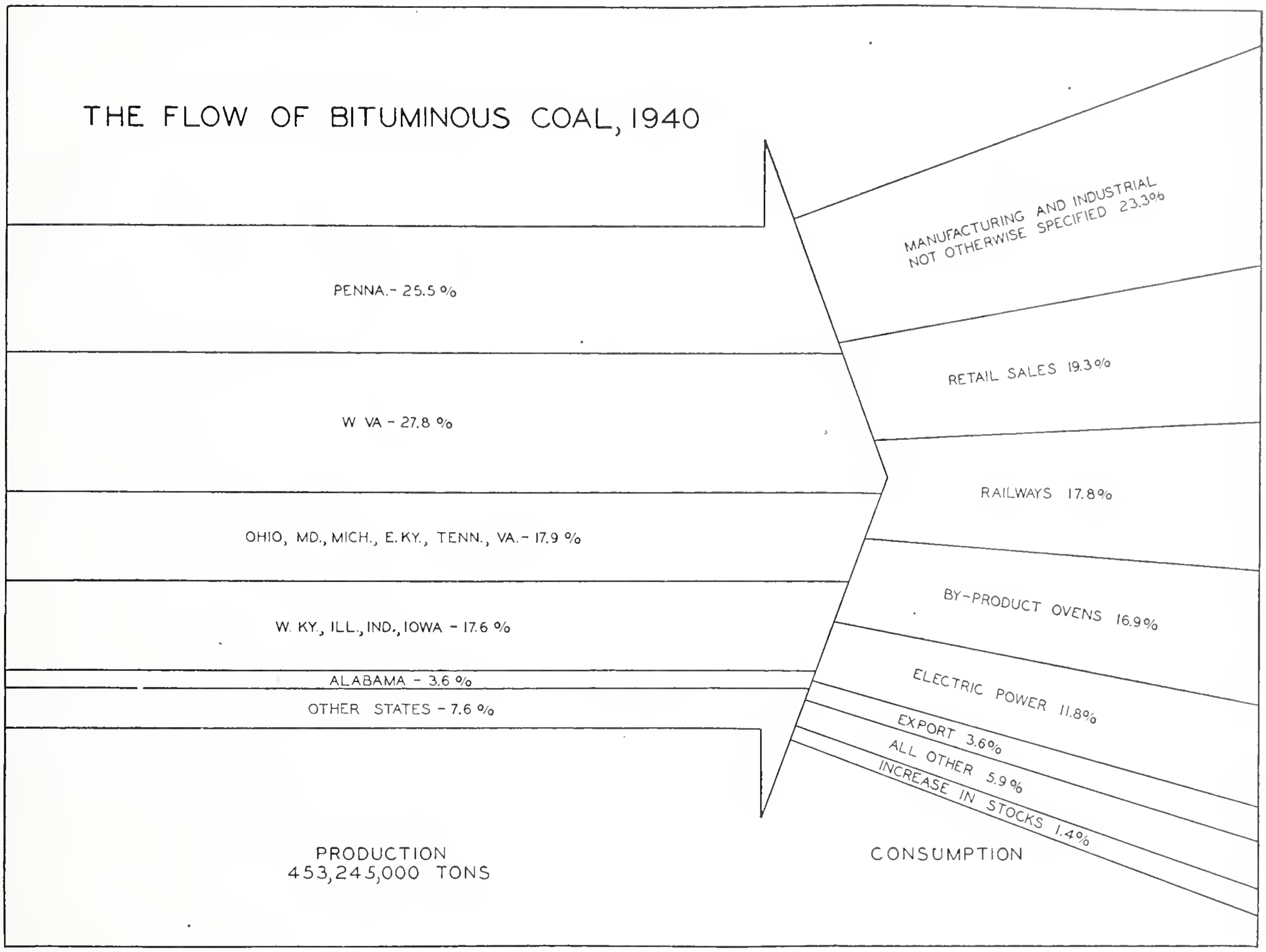


FIGURE 21

Lake Cargo. Coal that moves by lake freighters to various consuming centers along the shores of the Great Lakes is referred to as lake cargo coal. For the 1940 season more than two-thirds of this coal originated in the Southern Appalachian fields and approximately one-quarter in western Pennsylvania. Southern fields have gained in this trade largely at the expense of the Ohio and northern West Virginia field. See Table 10. Movement of lake cargo coal in 1940 involved 46,500,000 tons.

TABLE 10. TRENDS IN LAKE CARGO COAL SHIPMENTS

Producing fields	*Percent for years*		
	1920	*1930*	*1940*
Northern West Virginia	6	4	4
Southern West Virginia, Virginia, Eastern Kentucky, Tennessee	27	66	68
Pennsylvania	33	24	24
Ohio	34	6	4

Westward Rail Movement. The westward all-rail movement is by far the heaviest. 83,000,000 tons were moved in 1940. The heaviest movement is from the southern low-volatile districts, although a considerable amount of western Pennsylvania high-volatile coal (12.4 percent) enters this movement of coal to the west.

Coking and Chemical. The coke industry is the second largest industrial consumer of bituminous coal. The war revived the production of beehive coke and many beehive ovens in the coke region were repaired and put into production to aid the war effort. Much small-size coke was recovered from the old screening dumps at the site of old beehive ovens. However, it is likely that in the immediate post-war years most beehive coking will stop and the production of coke will be almost entirely from by-product ovens.

Western Pennsylvania produced approximately one-half of the nation's production of by-product coking coal in 1937. See Table 11.

TABLE 11. PRODUCTION OF BY-PRODUCT COKING COAL BY MINING DISTRICTS

	District	*Millions of tons*
1.	Central Pennsylvania	2.2
2.	Western Pennsylvania	25.2
3.	Northern West Virginia	1.8
7.	Southern #1 (low volatile)	11.1
7.	Southern #1 (high volatile)	1.6
8.	Southern #2	13.0
	Total	54.9

An increasing amount of coal enters various phases of the chemical and manufacturing industries, either starting with coke or with the by-products of the coke industry. Synthetic rubber and plastics are developments promising to use an increasing amount of coal. The transformation of coal into synthetic rubber and plastics is shown on figure 24.

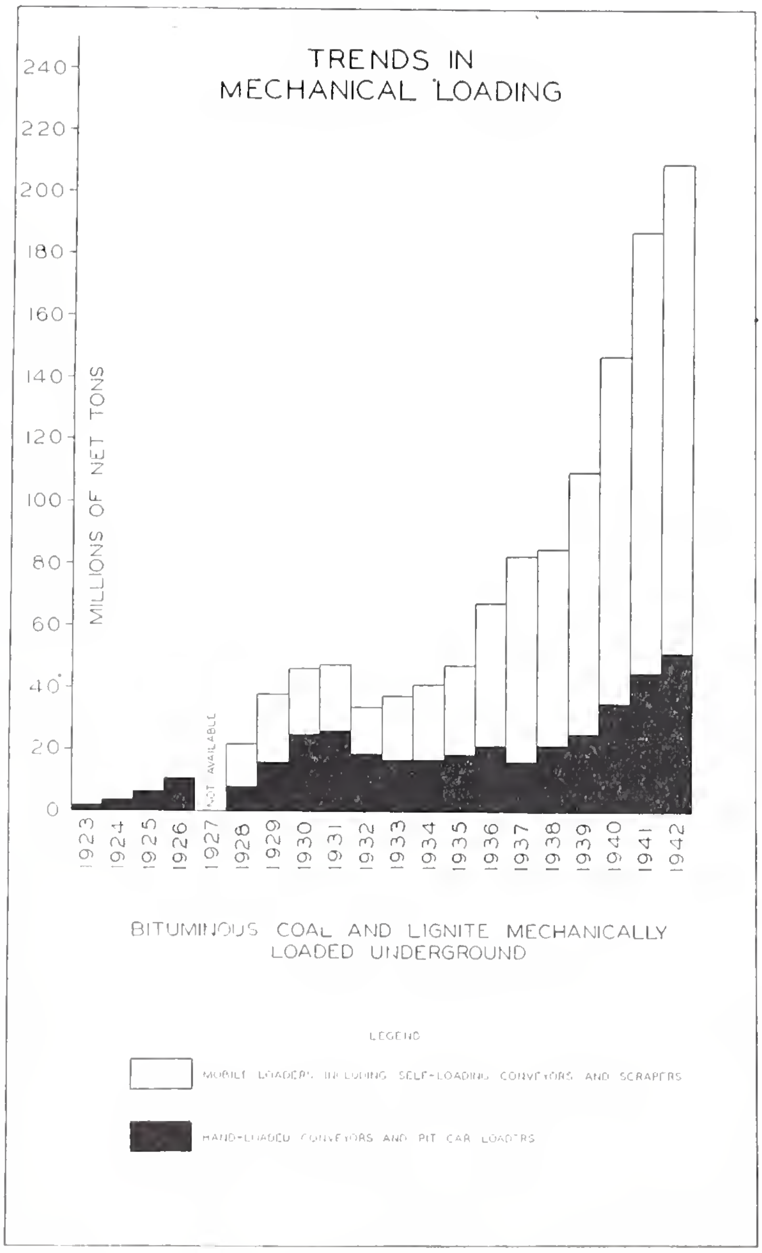


FIGURE 22

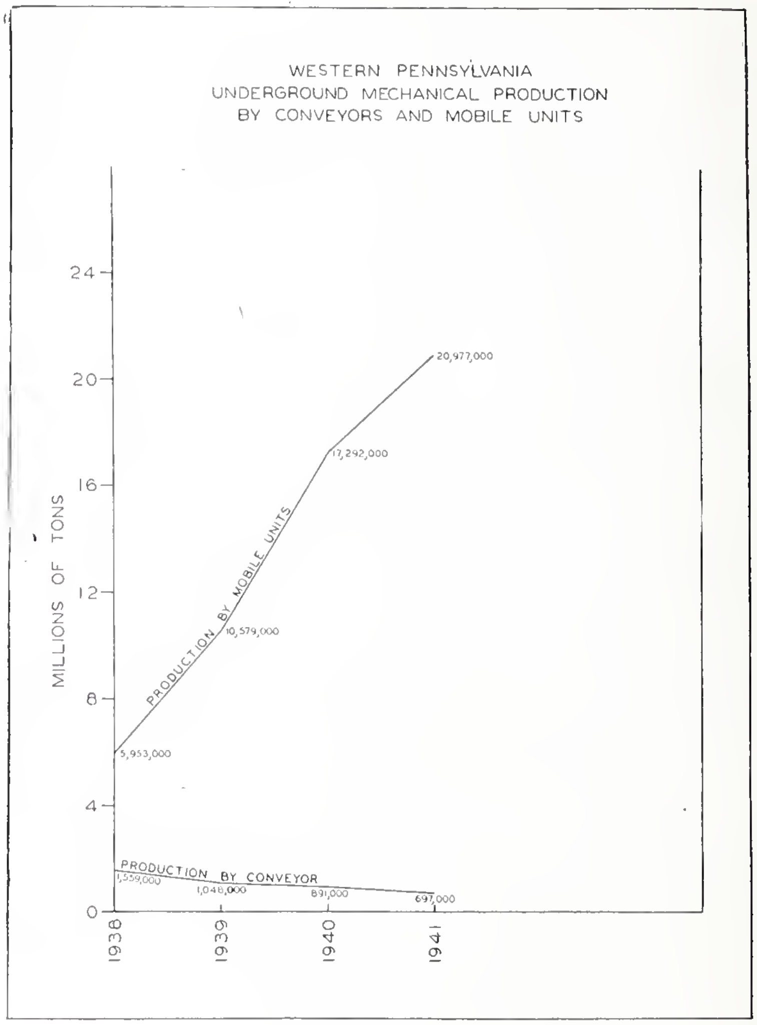


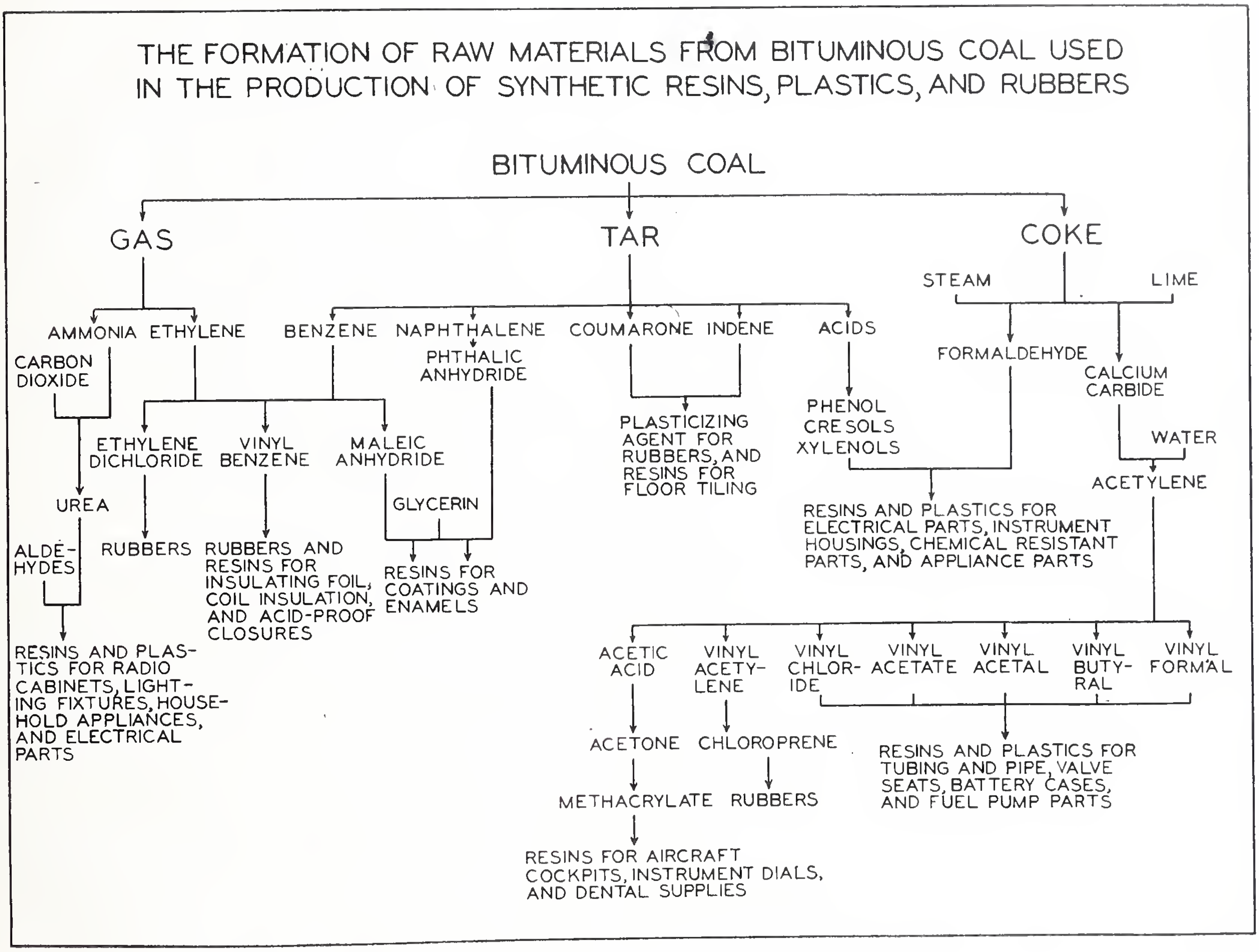
FIGURE 23

The use of bituminous coal in colloidal fuel mixtures is more than a probability. The direct production of certain dyes from coal and the production of a solution of coal in organic liquids has been proved to be technically feasible in the Mineral Industries Research Station of The Pennsylvania State College. Hydrogenation of coal to produce gasoline and allied products in competition with like products from the petroleum industry is technically possible but will probably not be economically feasible for at least another generation.

High grade carbon for electrode manufacture and synthetic activated carbon are being produced from coal. An increased amount of coal will be used for the manufacture of gas for fuel and as a starting material for chemical processing.

Combustion devices for coal have been greatly improved. An increasing amount of coal will replace petroleum and natural gas for industrial use and home heating. It is now possible to have an entirely automatic air-conditioning system for the home, apartment, and business buildings—heating, cooling, air filtration, and control of humidity in one unit operated

FIGURE 24


THE FORMATION OF RAW MATERIALS FROM BITUMINOUS COAL USED IN THE PRODUCTION OF SYNTHETIC RESINS, PLASTICS, AND RUBBERS
BITUMINOUS COAL
GAS
TAR
COKE
STEAM
LIME
AMMONIA
ETHYLENE
BENZENE
NAPHTHALENE
COUMARONE
INDENE
ACIDS
CARBON DIOXIDE
PHTHALIC ANHYDRIDE
FORMALDEHYDE
CALCIUM CARBIDE
PHENOL
CRESOLS
XYLENOLS
WATER
ETHYLENE DICHLORIDE
VINYL BENZENE
MALEIC ANHYDRIDE
PLASTICIZING AGENT FOR RUBBERS, AND RESINS FOR FLOOR TILING
ACETYLENE
UREA
GLYCERIN
RESINS AND PLASTICS FOR ELECTRICAL PARTS, INSTRUMENT HOUSINGS, CHEMICAL RESISTANT PARTS, AND APPLIANCE PARTS
ALDEHYDES
RUBBERS
RUBBERS AND RESINS FOR INSULATING FOIL, COIL INSULATION, AND ACID-PROOF CLOSURES
RESINS FOR COATINGS AND ENAMELS
RESINS AND PLASTICS FOR RADIO CABINETS, LIGHTING FIXTURES, HOUSEHOLD APPLIANCES, AND ELECTRICAL PARTS
ACETIC ACID
VINYL ACETYLENE
VINYL CHLORIDE
VINYL ACETATE
VINYL ACETAL
VINYL BUTYRAL
VINYL FORMAL
ACETONE
CHLOROPRENE
RESINS AND PLASTICS FOR TUBING AND PIPE, VALVE SEATS, BATTERY CASES, AND FUEL PUMP PARTS
METHACRYLATE
RUBBERS
RESINS FOR AIRCRAFT COCKPITS, INSTRUMENT DIALS, AND DENTAL SUPPLIES

by an automatic coal-fired stoker. This unit also furnishes the hot-water requirements.

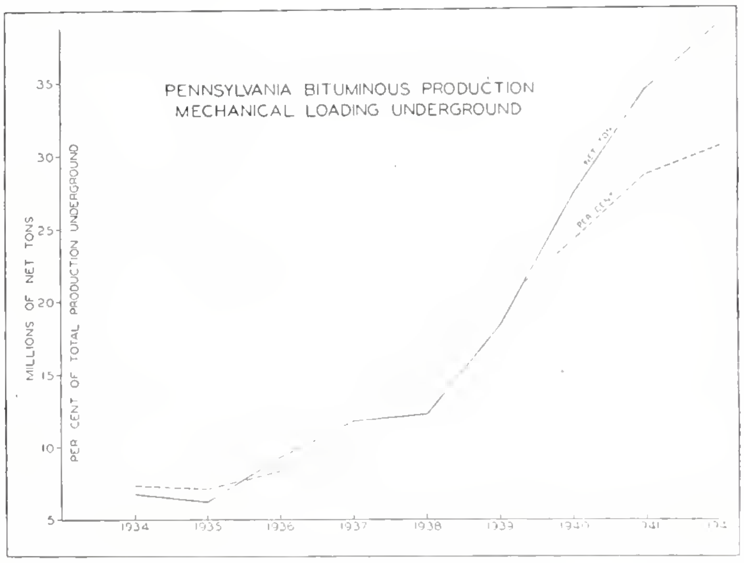


FIGURE 25

TECHNOLOGICAL ASPECTS

"What's wrong with anthracite" has been a favorite topic of conversation for so many years that one is prone to overlook the fact that this interesting mineral has served mankind for well over a century and a quarter. Such a defeatist attitude is really a reflection on our own ingenuity and the real question is what is wrong with ourselves that we are not able to get more out of this great natural resource. To illustrate its versatility several uses other than fuel to which anthracite has been or is being put are cited. These include filter medium, manufacture of graphite, foundry facing, reduction of ores, sintering of ores, carbon refractories, carburizer, heat-transfer tubes, battery plates, flash-light batteries, diaphragm plates, carbon structural forms, acid-resisting vats, etc., paint pigment, carbon brushes, carbon electrodes, telephone granular carbon, activated carbon, paper mill digester blocks, explosives, desludging agent in oil refining,

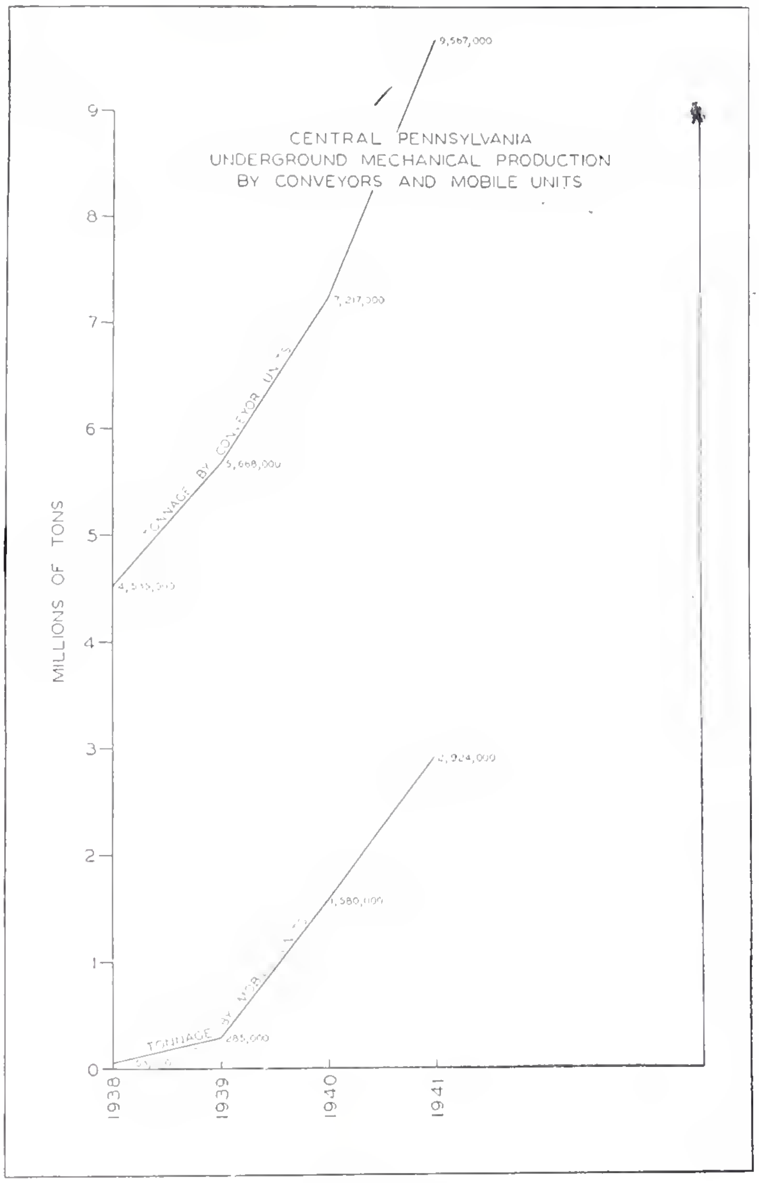


FIGURE 26

mineral wool, black concrete roads and manufacture of gas. This list is probably incomplete, nevertheless, it illustrates the versatility of anthracite.

Being essentially a carbon, it has found many uses as a carbon, none of which has been extensive. One very important use has been as the raw material for production of transmitter carbon in telephones. In more recent years it has been used under the trade name of anthrafilt as a filter medium in water treatment.

The use of anthracite as an activated carbon was studied during World War I by the U. S. Bureau of Mines, Why development along these lines was not continued to the commercial stage is hard to see unless it was due to the fact that large tonnages are not involved. Coal producers in general are tonnage minded and as a rule will give no thought to outlets that involve small quantities, even though such quantities can usually be sold at a profit. The Mineral Industries Experiment Station has recently studied this subject and finds that excellent activated carbons can be made from anthracite.

Anthracite has been used in the United States as generator fuel in the manufacture of carbureted water gas since 1872. The steady rise of water-gas production during the latter part of the 19th century and early part of the 20th century is reflected in the increased use of anthracite for this purpose until about 1919, when a peak of well over one million tons of the generator sizes—grate, broken, and egg—found a ready market in the manufactured gas industry. Subsequent to 1920, however, the use of anthracite tapered off slowly until the prolonged strikes of 1922 and 1925-26, when anthracite was very largely displaced from this market by other fuels. During the early twenties the undependability of supply resulting from labor difficulties, increasing prices, and lack of careful preparation which resulted in high ash content, forced the gas industry to the development of operating methods and equipment for the utilization of other fuels. The result has been that during the past decade the sales of generator anthracite fell to a low of 33,000 tons with a peak of only 88,000 tons. This was despite the fact that over 80 percent of the nation's 157 billion cubic feet of carbureted water gas was in 1939 produced in a 300-mile radius of the heart of the anthracite region.

The Mineral Industries Experiment Station conducted investigations in two small commercial gas plants, using a variety of anthracite and studying the various factors involved in such operations. In general it was found that anthracite, the densest and most concentrated form of commercial carbon, allows greater weight of fuel bed and permits more heat to be stored in the bed during the blow than do other solid fuels. As a result the average lowering of fuel-bed temperature during the steaming period is small, resulting in high percentages of steam decomposition, and low steam consumption per thousand cubic feet of gas.

Water gas is chiefly a mixture of hydrogen and carbon monoxide. The composition of this gas can be adjusted to form a synthesis gas from which many organic chemicals can be made. These include motor fuel, alcohols, acids, ethers, and esters, aldehydes and ketones, hydrocarbon and cyclic compounds. Furthermore, carbon monoxide is an important raw material in the synthesis of many other organic chemical materials, such as plastics, and producer gas can be used in the synthesis of ammonia.

The whole field of organic chemical industry will present new opportunities following the war. Coals of all ranks are logical raw materials for this industry. Anthracite has certain possibilities via the generation of water gas followed by catalytic synthesis. Commercial manufacture of oxygen will be much cheaper following the war, hence consideration should be given to water-gas generation using oxygen and steam. Above all it will be important to consider diversified and balanced industry, such as is illustrated by the figure 27.

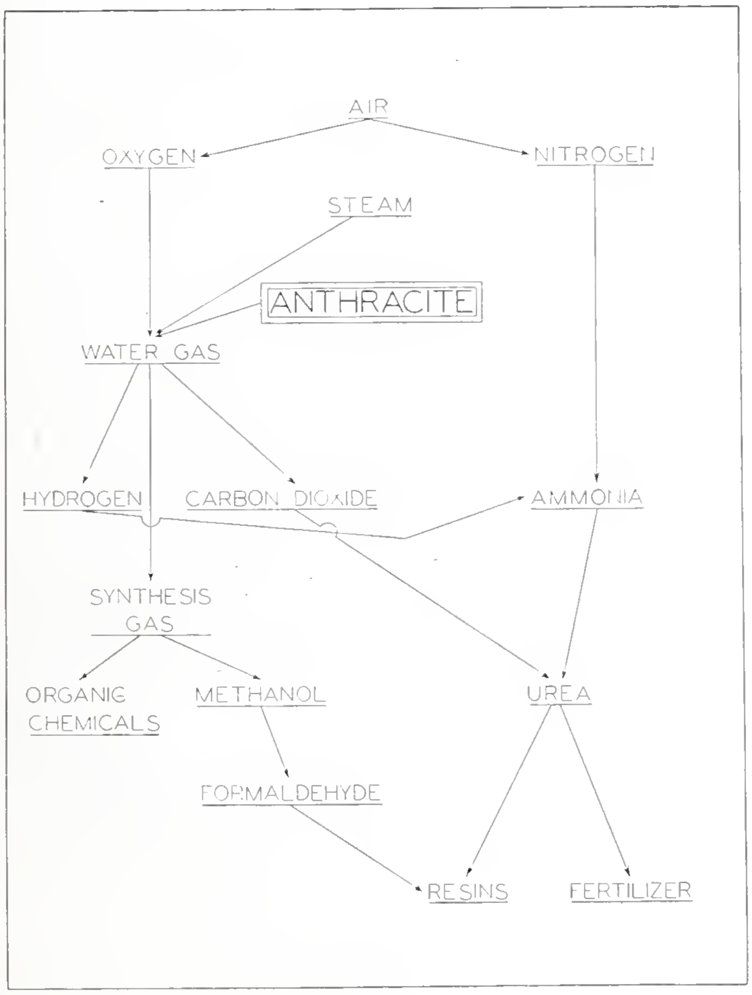


FIGURE 27

INTERRELATIONSHIPS AMONG FUELS

The anthracite, bituminous coal, petroleum, and natural gas industries are not independent of one another and yet they are independently operated, independently regulated, and highly competitive. To understand the development and trends of any one of these industries requires an understanding of the fundamental relationships among the four of them. These industries have been highly competitive from the very beginning of their exploitation in Pennsylvania. Thus, oil obtained by distillation of coal sought to supplant whale oil in lighting and was almost immediately replaced by kerosene from petroleum; in fact, the term coal oil, for lamps, persisted long after lamp fuel was obtained almost solely from petroleum. Later, illuminating gas and electricity supplanted kerosene and the coal industry thereby regained most of the lighting market.

Similarly anthracite was introduced early for the smelting of iron, only to be replaced by coke from bituminous coal.

A brief consideration of the organization of these industries is essential to an understanding of their inter-relationships. Anthracite is mined mostly within Pennsylvania, prepared for the market and sold almost entirely for energy purposes—chiefly for domestic heating. The limited use of anthracite other than as a fuel for direct combustion, such as in the manufacture of gas, is not a function of the industry itself but is in the hands of utilities that purchase their fuel from the anthracite operators. Because the industry has not been close to the ultimate use of its product for many years it was not concerned with the manner in which it was used. The problems of the consumer were considered not to be problems of the industry and few if any developments in the art of consumption may be traced to the industry itself. Such advances as were made, as for example, in the domestic stoker or magazine heater, came from equipment manufacturers and not from the industry. In the last decade many in the industry have come to the conclusion that such an attitude can only lead to disaster and the industry is sponsoring an extensive research program seeking to correct this situation.

The bituminous coal industry comprises two parts, one of which consists of the so-called commercial mines which mine, prepare and ship coal to the consumer, the other consisting of the "captive" mines which are subsidiary to other industries, chiefly the steel industry. In the latter the coal is mined and to a large extent used in the production of other products, such as power, coke, gas, ammonia, and benzol. In a number of cases commercial collieries also are manufacturers of coke and by-products. Here, as in the anthracite industry, the commercial mines are little concerned with problems of utilization. Problems of mining and preparation were acute, and coal was prepared carefully because it could not be sold otherwise, except at a low figure or with great difficulty. On the other hand, the captive mines had to be concerned with phases of utilization, so developments in by-product coking is a concern of steel companies and equipment manufacturers. Also developments in the big field of utilization, namely, combustion, may be traced entirely to equipment manufacturers and large users, such as utilities. The domestic market was entirely neglected except for the small developments by stove and domestic stoker manufacturers. The domestic stoker originated in the West and in consequence of having a free-burning fuel with which to work never reached a stage of development that gave an appliance suitable for the heavily coking coals of Pennsylvania. This is now in the process of correction as the result of the development of a new stoker designed especially for Pennsylvania coals in a research program sponsored jointly by the Commonwealth of Pennsylvania and the bituminous coal industry.

There is now a growing trend in the bituminous coal industry to recognize that the realization of the highest utility of coal can only come about through cooperative efforts of the coal producer, the equipment manufacturer, and the fuel technologist.

The petroleum industry of Pennsylvania differs sharply from the two solid fuel industries in that only 14 percent of its raw material is produced in Pennsylvania. The balance comes from other parts of the United States, from Latin American countries and, following the war, may be expected to come from other more distant foreign lands. The petroleum industry parallels to some extent the bituminous coal industry in that there are a large number of independent producers (comparable to the commercial mines) and certain major companies that not only produce but buy and refine oil. Unlike the commercial mine, however, the petroleum producer is limited in his market outlet and there has been a uniformity of price per unit of a given quality oil that did not exist in the coal industry prior to the bituminous coal code of NRA days.

The Pennsylvania industry must compete with refined products of petroleum from other parts of the United States. It does this in part with commodities such as Penn Grade lubricants produced from Pennsylvania Grade Crude and in part with products refined in Pennsylvania from petroleum brought in from other localities. However, there has been a reasonable stability of price in the refined products, which the bituminous coal industry never knew up to the time of the establishment of minimum prices by the Federal Government. There has been a certain degree of self-regulation within the petroleum industry of the United States during the past decade, which has also been unknown in the bituminous coal industry, but which has had a counterpart in the anthracite industry during the past five years.

The petroleum industry has been characterized by its ability to adapt its operation to the demands of society. Thus, when the heavy demand was for kerosene, its main product was kerosene. When the demand for motor fuel and lubricants stepped up at an increasing pace, the industry found ways of increasing the yields as well as improving the quality of these products. For a long time petroleum was chiefly used for production of kerosene, motor fuel, and lubricants. It still remains our chief—in fact, almost sole source of these products. However, the last two decades have seen tremendous advances in the technology of petroleum as well as severe competition with coal for the heating market. Of late years, in direct consequence of the increase in knowledge of petroleum resulting from an enormous research program within the industry, it has become a major chemical industry and now competes with such derivatives of coal as benzol, toluol, and solvents. This competition may be expected to increase in intensity in the post-war period and will increase so long as ample supplies of crude petroleum are available. The coal industry can meet the problems presented by such competition only by a vigorous research program of its own which will seek to learn more of the constitution of coal in order that methods may be discovered of extending its use as a raw material. Inasmuch as coal, petroleum, and natural gas are all composed chiefly of carbon and hydrogen, there is every reason for assurance that coal can improve its position as a raw material for the chemical industry.

The known proved reserves of natural gas in the United States are estimated to be 85 trillion cubic feet, or about 30 years' supply at the current rate of consumption. The major fraction of this is in States other than Pennsylvania. However, its existence is important to Pennsylvania because the development of long-distance pipelines makes it possible to bring the gas to the center of demand. Pennsylvania consumers have had long experience with natural gas—the industry had its beginning in Pennsylvania—and this fuel will be in demand so long as it is available at a price competitive with manufactured gas. However, its chief utility will always be as a fuel since the cost will be too high for consideration as a raw material, except insofar as the higher hydrocarbon components of the so-called wet natural gas are concerned.

The industry has a very diverse organization. It is not only a producing industry but is engaged in purchase, distribution, and sale as well. Since much of it is classed as a public utility, it has been subject to governmental regulation for many years and the quality of its product, the sale price, and its earnings are all fixed.

In Pennsylvania, from the standpoint of production, all of these industries are in the stage of maturity. As has already been clearly shown, this in itself presents them with many problems of recovery that must be solved if the Commonwealth is to retain a satisfactory economic position. One may argue that petroleum and natural gas are not of concern insofar as anthracite and bituminous coal are concerned because depletion has already taken such a heavy toll. However, this would be tantamount to hiding one's head in the sand because the development of transport in all forms has resulted in bringing huge supplies of the fluid fuel into the State from sections of the country hundreds of miles away. And the cessation of hostilities will be followed by importation of petroleum by tanker from far distant lands.

Since the mineral fuels are composed largely of the same chemical elements and consequently may serve as raw materials for production of energy or organic chemicals, it would seem logical to treat them as such and to use each for its highest purpose, to conserve each, and to develop the use of each to the highest degree of efficiency.

As fuels, natural gas and fuel oils have the advantage of convenience. The public likes this and after the war will demand as nearly automatic heating as it is humanly possible to attain. The war has taught us that all fuels are vital to our national existence. It has also taught us that, for certain purposes, petroleum is indispensable. Now it is true that motor fuel can be made from coal but only at high cost and then in quality that does not compare favorably with the product from petroleum for use in modern aircraft engines. Recent laboratory studies have demonstrated that high volatile coals such as occur in Pennsylvania in large tonnages are suitable for conversion to petroleum equivalents. To a man from another planet it would not seem to be a very sound national policy to burn as a fuel 35 percent of a raw material, already scarce, that is needed for manufacture of gasoline. Yet that is what this country was doing up to the present war.

On the other hand, this is no argument for insisting that the citizens of this country should be satisfied with antiquated and inefficient equipment, poor quality fuel, and shortages due to work stoppages of one kind and another, and yet that has been the effect of the attitude of much of the coal industry to date.

These industries should be drawn more closely together. In fact, they should not only be cooperative but they ought to be complimentary. All of the fuels can supply gas where it is needed. Coal gas and natural gas are now mixed and marketed in some communities. Gas should be made from coal in by-product plants and from anthracite and coke in water-gas sets. In some localities it will be possible to store this gas in depleted natural gas sands under ground and thus clean up the last of the natural gas therein. The gas can be fed into the many pipe lines already available and piped to consuming markets. Gas for kitchen use will then be available and those who wish to bear the added cost can use it for space heating. Certainly it is foolish to consider the curtailment of the use of gas when its advantages are so well known.

The welfare of the nation may dictate that no fraction of petroleum be used as a fuel so long as motor fuel and lubricants can be made from it. Should this event come to pass, it is no reason for asking the householder or the small apartment owner to burn coal in the same inefficient manner that his father did. We must experiment and study and learn how solid fuels actually burn and then develop equipment that will give efficient services as nearly automatically as is humanly possible. Nor will the solution of this problem be final, for further researches may lead to cheaper ways of liquefying coal or new heating techniques, such as an operation the reverse of the electrical refrigerator, or central heating plants to provide for whole towns or sections thereof.

TRENDS IN THE PENNSYLVANIA OIL-PRODUCTION INDUSTRY

IN VIEWING and weighing the future of the oil industry of Pennsylvania, two main questions are to be considered:

1. How long will the visible reserves of oil last and how much of them can be recovered by present methods and by possibly improved future methods?

2. Can new oil fields be discovered and by what discovery methods, and in what volume can these invisible reserves be expected to be brought to market?

Reserves of Crude Oil

Various estimates of oil yet in the ground in known oil pools have been made from time to time. A recent compilation (1941) made by the Pennsylvania Grade Crude Oil Association and submitted to the Office of Price Administration gives the following figures:

District	*Recoverable by present methods in barrels*	*Total oil reserves in barrels*
Bradford	134,400,000	874,103,000
Middle (Kane-Butler)	263,300,000	2,074,457,000
S. W. Pennsylvania	130,940,000	630,921,000
Total	528,640,000	3,579,481,000

The term "recoverable by present methods" includes nonstimulated primary production as well as the secondary productive methods known as water-flooding and gas and air drive. A breakdown of the oil production figures into primary and secondary is not available but a judicious guess would place the contribution of secondary recovery in Pennsylvania at about 90 percent of the total present yearly production. It can be seen that the ultimate application of the most modern methods of oil production according to present standards will still leave unrecovered some three billion barrels of oil of the highest grade known in the world. To devise methods that will recover this oil economically constitutes a considerable challenge to the ingenuity of the petroleum engineers and scientists. The problem may be attacked and has been under invstigation from various angles.

It is generally believed that the efficiency of water-flooding, which still leaves in the sand some 30 percent of oil originally in place, can not be increased. Studies of the flooding mechanism have been in progress for over ten years and indeed great strides have been taken in the application of scientific principles to actual field application in water-flooding. It is, however, doubtful that the final sand saturation of floodable properties can be reduced below 20 percent and many properties and sands (particularly in the Kane to Butler district) are not considered as floodable. In some of them gas and air drive is resorted to as the next best approach to the problem of recovering additional oil from sands considered as depleted by primary methods. Unfortunately, such methods still leave behind on abandonment a sand saturated to the extent of 30 to 50 percent oil. The ultimate limits here mentioned seem to be inherent in the mechanism of water or gas drives and numerous laboratory evidences indicate that they can not be brought down by conventional practices. Accordingly, departures from the presently accepted practice of secondary recovery have been suggested and have at times been called "tertiary recovery methods" as some of them, if successful, might be applied to properties that have previously been depleted by the successive application of primary and secondary methods.

A method which can perhaps be classed as "tertiary" is that of making use of "gravity drainage" as the main propulsive drive. This is at times called "oil mining" because it implies a certain amount of shaft sinking, galleries driving, as well as drilling. Experiments that are receiving considerable attention are those conducted at the mine near Franklin, Venango County; information received at this time is too scanty to permit judgment at this writing, but the experiments are well worth watching. Except for the development of horizontal drilling equipment, the use of gravity drainage is not new as it has been in use successfully for several decades in France at the Pechelbron oil mine (Alsace) where drainage wells are drilled into the producing sands from horizontal galleries driven underneath the oil-bearing horizons.

A second departure from ordinary lines of thought in recovering a third crop of oil would consist in using solvents. Two classes of solvents are considered:

liquids and gases. It is not generally believed that liquid solvents will prove economical as those suitable command a price comparable to or greater than the oil to be recovered; therefore, the problem of flushing the solvent out of the depleted sand would probably be a greater one than the oil recovery itself. Of more interest is the consideration of the use of the solvent power of certain gases under high pressures. The problem of recovery of the solvent after depletion would be a minor one as it could be produced from the depleted oil field in a manner similar to gas field production. Preliminary experiments have been carried out with the use of carbon dioxide, a very cheap waste gas, but as was to be expected, the solvent power of the gas in the retrograde region is greater for light hydrocarbons in the gasoline range than for those in the desirable lubricating range.

Perhaps of more interest to Pennsylvania oil production is the possibility of underground oil gasification or at least of injection of hot gases and liquids in the oil-bearing sands. This idea is particularly interesting in Pennsylvania in view of the fact that the greatest quantity of so-called unrecoverable oil is present in the Kane to Butler area where the character of the sand reservoir is particularly suitable to the application of this method of tertiary recovery. It seems that the thermal recovery idea originated in Russia where the products of pressure gas combustion were directly injected into the producing sands. A rate of production equal to or greater than the primary rate was reported shortly after the application of the hot gases. The production products varied considerably over the period of thermal rejuvenation, showing a gradual reduction of the heavy hydrocarbon with time, and indicating the possibility that an underground fire was actually started.

It is reported that both the solvent and gasification methods are presently being given a field tryout in California. No information on the results is as yet available.

Invisible Reserves of Crude Oil

The recognized potential oil-producing areas of Pennsylvania have not as yet been fully explored either by the judicious use of geology and geophysics or by the drilling of a sufficient number of wildcat wells. During the past decade, the Pennsylvania Geologic and Topographic Survey has been engaged in a most fruitful work of assembly and coordination of geological data which is helpful in understanding the mode of occurrence of oil in western Pennsylvania. Already it is possible to arrive at the conclusion that known oil-productive sand bodies in Pennsylvania are definitely of the shore-line and off-shore line type; in other words, that the productive horizons occur in a narrow belt deposited along the shores of ancient seas. As these shores receded over geologic time in a northwest direction the youngest producing horizons are found in parallel trends displaced to the northwest and progressively shallower. We have for instance the Venango Sands trend, the best known as it is the most completely developed, which forms a belt about 20 miles wide extending through western Greene County, central Washington County, western Allegheny County, Butler, and Venango Counties. Parallel to this trend and to the east we have the Warren Sands group fairly well developed in eastern Warren County but inadequately developed and poorly explored to the southwest in a direction parallel to the Venango Sand trends. Further east and older geologically, we have the Bradford Sands trend, well developed and explored in McKean County but inadequately prospected in a direction parallel to the Venango Sand group. This extension of the Bradford Sand trend would include northwestern Elk and Jefferson Counties, Armstrong County, western Westmoreland and Fayette Counties.

It may be objected that these trends have been explored extensively for natural gas. However, one must bear in mind that the natural-gas exploration has been essentially structural, whereas the prospecting for oil must be essentially stratigraphic in character.

Stratigraphic exploration can be helped considerably by a proper understanding of the geological principals involved in the formation of sand bodies along shore lines, but it must be borne in mind that geology can at best only indicate a relatively wide belt in which favorable sedimentary conditions prevailed during a given geologic period. A study of the available well records and samples may narrow the favorable area somewhat but when one considers that a sand body

Petroleum Refinery
by Christian J. Walter

may be as narrow as 500 to 1000 feet, the job of "pinning-down" the location of the exploratory well within such a narrow belt is too much to expect from broad geological considerations. Possibly it is even too much to expect that the "pinning-down" can be done even if a well were available every mile with complete geological records and samples.

Two avenues of exploration are open in trying to prospect the trends here above mentioned: random drilling and the judicious use of the appropriate geophysical and geochemical exploration methods.

Thus far the incentive to drill at random a large number of wells has been insufficient. The one who would engage in such a campaign must expect perhaps not more than one discovery for each 20 to 25 wells drilled.

Concerning geophysical and geochemical prospecting, no method has thus far been developed which will determine the depth, extent, and fluid content of a sand body. In this work several known methods, highly successful in other parts of the United States of America, can be ruled out as they are structural prospecting tools: namely, the seismic, gravimetric, and magnetic methods. As possible stratigratic discovery tools there are left the electrical, geothermal, and geochemical methods (including those making use of radioactive or nuclear physics). Electrical methods have been and still are receiving considerable attention, and various approaches are indeed very promising though in the early experimental stage. If one includes electrical well logging, geo-electrical measurements are indeed of the greatest importance in the study of stratigraphic conditions. But it is in the measurement of electrical logs from the surface that the tool holds the greatest promise of discovery.

Geochemical methods, both as soil analysis and hydrocarbon leakage measurements, have been tried out in Pennsylvania but without a great deal of success, at least as far as the discovery of prolific fields is concerned. No doubt great improvements are still needed in this line of thought.

Those geochemical methods making use of nuclear physical phenomena have not as yet received much attention in Pennsylvania. They could no doubt contribute a great deal to stratigraphic studies of cased wells. Surface radioactive prospecting is yet in its infancy and, on theoretical grounds, grave doubts have been expressed as to its feasibility.

Geothermal measurements in wells and on the surface have been almost totally neglected though it might be well to watch developments in this field of study.

The oil prospector should not be unduly discouraged if a new geological or geophysical thought does not pay dividends the first time it is applied to the locating of a wildcat well. At best, the new methods will be successful only a fraction of the number of times used. If a method is to prove to be correct in its predictions once in five when based on a large number of trials, the odds against the first well are at least 4 to 1; against the two first wells they are 16 to 9, and even for the first five wells they are an appreciable fraction, about one to three.

THE FUTURE OF PENNSYLVANIA OIL

A consideration of the future of Pennsylvania oil involves an appraisal of the future of the production of Pennsylvania crude and the possible finished products which will be manufactured from this raw material. It is quite obvious that an industry must have raw materials in order to exist but in addition the finished products must be sold to the consuming public in competition with similar products from other sources at a fair profit.

According to recent predictions based upon the known reserves of crude oil and the present rate of withdrawal and utilization of these reserves, the future life of the Pennsylvania oil fields is of the order of magnitude of the average productive life of all the oil-producing areas in the United States. This may be a bit surprising in view of the fact that the Pennsylvania fields are the oldest commercial producing fields in the world. While the picture may change at any time with the discovery of large reserves in Pennsylvania or elsewhere, this condition is substantially true today. This is quite heartening because it is almost equivalent to saying that there will be a Pennsylvania oil industry at least as long as there is any oil industry. This does not necessarily mean that one depends upon the other but, as will be pointed out later, they are closely interrelated.

The history of most mineral industries shows that the leaner and less accessible accumulations are utilized in the later life of the industry. In some cases the waste pile or the rejects of the industry may be processed economically. This seems to be also true in the petroleum industry. The early oil fields were shallow and relatively easily found. As the sensitivity of the instruments for locating possible oil accumulations increased and more rugged drilling tools were developed, deeper and deeper oil reservoirs were discovered. This trend has continued and, as a result, within the past few years the cost of finding and producing a barrel of crude oil has been on the increase. What is more alarming is the fact that the rate of discovery of new petroleum reserves is lagging behind the rate of consumption.

This situation is stimulating the application of the best engineering knowledge to the exploitation of our known reserves. In addition, it is making the industry more conscious of the fact that after primary production (the production given to us by nature), secondary recovery methods (the production we take from nature by artificial means) should be applied wherever possible. This is an example of the need for improved technology as the deposits become leaner.

All of this points in the direction of an increased price for crude oil. This is as it should be but there is an economic upper limit to crude oil prices. This will be attained when the cost of producing this raw material plus its processing cost to form finished products equals the cost of other raw materials from which similar products can be produced plus their cost of processing. This, of course, assumes that the calculation is based upon comparable quantity and quality of the finished product. To put it in equation form:

$$\begin{array}{c}\text{Petroleum Production}\\ \text{Cost}\end{array} + \begin{array}{c}\text{Petroleum Processing}\\ \text{Cost}\end{array} = \begin{array}{c}\text{Other Raw Material}\\ \text{Production Cost}\end{array} + \text{Processing Cost}$$

It should be kept in mind that this represents a limiting condition. If the combined cost of producing and processing petroleum is less than that necessary in utilizing other raw materials for similar products, the petroleum industry is in a favorable position and the greater the inequality in this direction, the more favorable is the situation for petroleum. However, if the present trend of increasing consumption, decreasing rate in the discovery of reserves, and increased prospecting, developing, and operating costs continues, the price of petroleum must of necessity increase and other energy sources, especially liquid fuels, will come into active competition. The liquid fuel sources that are now "standing-by" for a favorable price are shale oil, the Athabaska tar sands, coal hydrogenation, the hydrogenation of carbon monoxide derived from coal or natural gas, and agricultural alcohol. All energy sources must be considered when the future of the petroleum industry is concerned. This includes coal, water power, and such potential sources as tide energy, wind power, direct solar energy, thermal energy from the earth, and atomic energy.

Just as the petroleum industry in general is economically related to other energy sources, so is the Pennsylvania petroleum industry related to the oil industry as a whole. This economic relationship for products of equal quality may be shown by an equation similar to one already discussed.

$$\begin{array}{c}\text{Pennsylvania Petroleum}\\ \text{Production Cost}\end{array} + \begin{array}{c}\text{Pennsylvania}\\ \text{Petroleum Processing}\\ \text{Cost}\end{array} = \begin{array}{c}\text{Other Crude}\\ \text{Production Cost}\end{array} + \begin{array}{c}\text{Other Crude}\\ \text{Refining Cost}\end{array}$$

Again this defines an economic limit under which the Pennsylvania oil industry can remain in competition with the rest of the oil industry. The price of Pennsylvania crude is considerably above that from other areas, which is a fortunate thing for the Pennsylvania producer since the cost of producing the crude is also considerably above the rest of the industry because a great part of the production is by secondary-recovery methods. A compensating fortunate circumstance is that Pennsylvania petroleum is capable of producing large quantities of very high grade lubricants with a minimum of processing. These bring premium prices and it is chiefly for this reason that the Pennsylvania oil producer can afford to spend more money to produce his crude. Similarly, the Pennsylvania refiner can afford to pay more for his raw material and compete successfully with refiners making lubricants from other crudes because he can produce the maximum quantity of a premium finished product from a barrel of crude with a minimum amount of processing.

The margin of safety for Pennsylvania oil has been decreasing in some respects because of improved methods of refining the lubricating-oil fraction of other crudes. These new refining methods have tended to improve the finished quality of lubricating oils from all crude oils but since the Pennsylvania oil is naturally good, the improvement in its quality has not been as marked as in the case of the poorer raw materials. The lubricants derived from Pennsylvania crude are still the finest available and this fact is recognized by industry. However, the quality of competing products im proving and the margin of advantage is narrowing.

In view of this trend, it would be of interest to look into the future in an attempt to ascertain the direction in which our technologic developments are taking us, how such changes might affect the oil industry, and what the oil industry might do to keep pace with the times.

As mechanization becomes more universal, the machines used become more complex, and their specifications become more exacting. Coupled with this go the necessity for fuels and lubricants of higher quality and more exacting specifications. The gasoline of yesterday was a very crude product as compared to the gasoline used in our airplanes today. The lubricants used in the past would not function nor hold up in the modern high speed engine where clearances are much less, temperatures and pressures are greater, and conditions in general are more drastic than they have been in years gone by.

These trends are affecting the oil industry today so that it is becoming more and more of an exacting industry which can function only under precise scientific control. As more is learned of the composition of petroleum and the chemical reactions that the individual compounds undergo, the refinery products approach closer to being pure chemical substances. The individual molecules are being tailored to exacting specifications. While the industry has been using such terms as gasoline fraction, kerosene fractions, and others for its products, it is now introducing such chemical names as iso-octane, cetane, and similar terms. Individual chemical compounds are being isolated from petroleum and sold as such, and the processing in many cases points to a very definite compound. Some examples of this are the production of iso-octane for aviation fuel, toluene for T.N.T., butadiene and styrene for synthetic rubber, glycerine, alcohols and a host of others too numerous to mention. The petroleum refining industry of the future will be concerned with such specialty products. The chief outlet for petroleum utilizing its inherent energy will be for the propulsion of various modes of transportation since it is about the most concentrated and conveniently available source of energy, which is necessary in a moving power generator. The use of petroleum products for the generation of power in stationary engines and as a source of heat may decline somewhat.

The internal combustion engine of the future will probably have a sealed lubricating system using a highly refined oil with certain additives to impart in a carefully controlled manner certain desirable qualities. In this closed system will be included a miniature refinery process for continuously removing harmful substances that are formed during use. It may not be necessary to change oil but simply add enough to replace what has been used up. Although increased mechanization will mean more engines to lubricate, less lubricant will be used per engine. One trend will offset the other and the total quantity of lubricant required may not change too much. However, the best lubricants available will be in the greatest demand and it is because of this that Pennsylvania oils will play an important part.

Knowing that such trends exist, the Pennsylvania petroleum industry is continually improving its products and creating new ones. Work has been and is being done on improving the methods used in producing Pennsylvania petroleum. Such effort must continue and even be expanded. Pennsylvania petroleum is an important natural resource and for this reason it must be conserved. Nature gave the Commonwealth of Pennsylvania by natural production about one-third of the oil, one-third more is being removed by secondary recovery operations, but one-third is still being left in the ground because of our inability to remove it economically at the present time. It is estimated that there are about 3½ billion barrels of Pennsylvania crude oil still remaining in the ground today which is about 3½ times as much as has been produced to date since the inception of the industry in 1859. This is one of the challenges of the future. It is quite obvious that the Pennsylvania oil industry must have this oil in order to stay in business.

Returning to the equation given previously, it is also necessary that the price of Pennsylvania oil be such that the industry can compete with crude produced from other areas. This means that the efficiency of production must be improved. Another method of meeting the competition from other petroleums is to improve existing products and create new specialty products which will demand a premium price. By increasing the revenue obtainable from each barrel of crude through new products, the price of crude could be higher or the cost of processing could be increased and still have an economic operation. The Pennsylvania oil industry must develop products that are unique to its raw material in order to maintain a permanent advantage.

To summarize the possible future of the Pennsylvania oil industry it may be said:

(1) The Pennsylvania industry has adequate crude to exist as long as the rest of the oil industry.

(2) The length of existence will depend upon certain economic factors, the chief of which is that the cost of raw material plus processing must not exceed that of competing products of similar quality.

(3) The Pennsylvania oil industry along with the rest of the petroleum industry is moving in the direction of specialty products.

(4) The inherent properties of Pennsylvania oil make them highly desirable products for our complex machines of today and the future.

(5) In order to maintain its competition with the rest of the oil industry, the Pennsylvania in-

dustry must continue and even expand its research work on improving the efficiency of oil production and in bettering its existing products and finding new products. A good portion of the 3½ billion barrels of Pennsylvania crude oil which are still in the ground, and which represent about 3½ times the quantity already produced, must be produced and processed in the future. This is a tremendous challenge to our research and engineering skill.

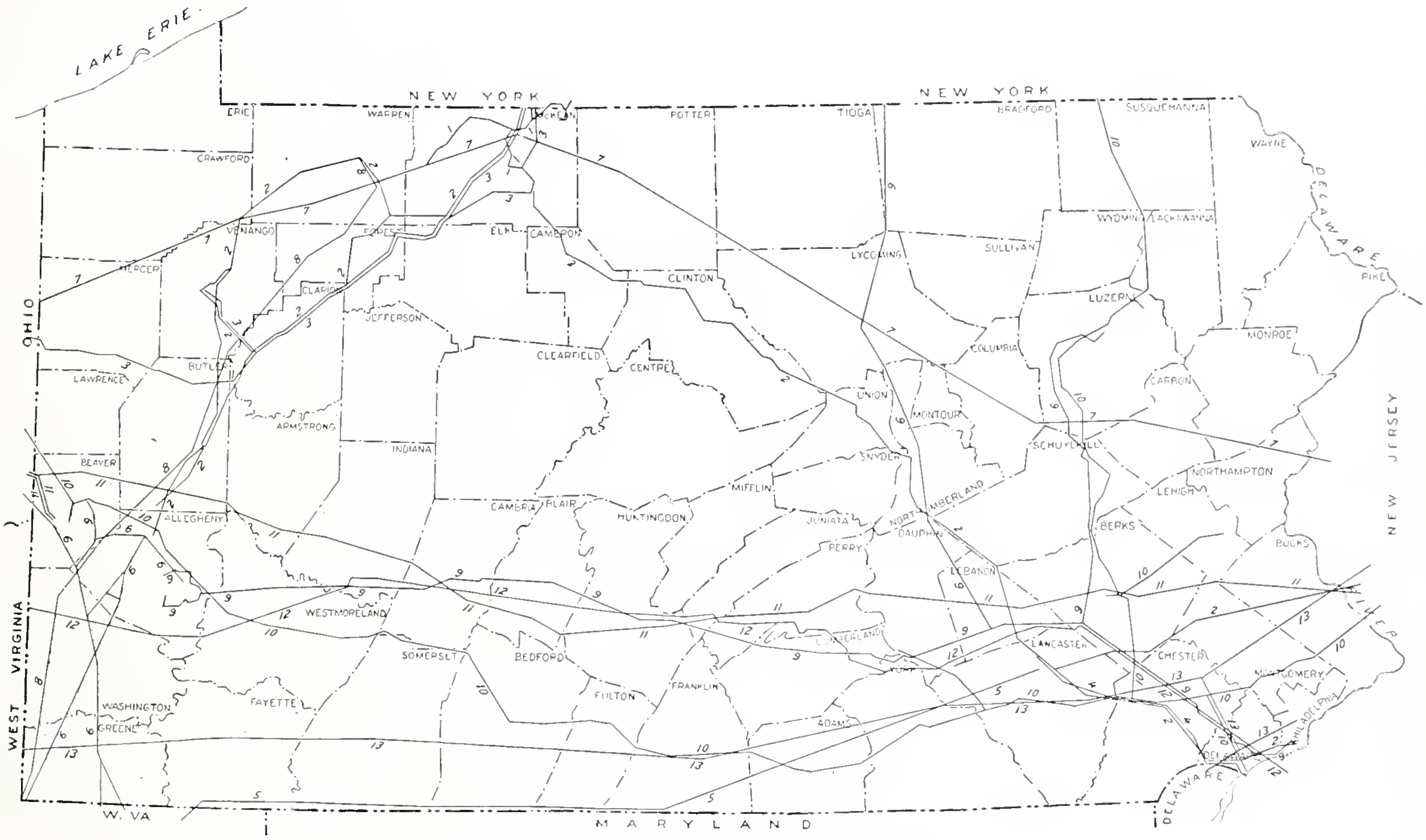


FIGURE 28. PETROLEUM PIPE LINES

NATURAL GAS

UNDER the impetus of the present period of national emergency, natural gas is rounding out the cyclic life typical of many of our other essential natural resources. First came its discovery and initial utilization in areas where the gas was first found. Following this occurred the period of improvement in production methods, transportation, and utilization which resulted in the creation of a more widespread demand for the fuel. The third phase of the cycle occurred when tremendous volumes were found in other sections of the country. Then followed a period of wastage of this valuable commodity until suitable and effective means of transportation could be arranged to bring the gas to areas where a combination of domestic and industrial markets could make use of the gas, principally as a fuel.

The fourth period of the cycle is now in evidence. That is the period of taking inventory, estimating reserves, and planning for future trends and developments. Occupying a high place as a desirable fuel for a wide variety of purposes, there are now indications that natural gas may prove even more valuable as a raw material for chemical synthesis.

Natural gas consists of a mixture of hydrocarbons, chiefly methane and ethane, but frequently with smaller though appreciable quantities of heavier gases, such as propane, butane, and pentane. As a general rule, methane represents from 80 to 99 percent of these gases, and ethane up to 20 percent, whereas the other gases, together with some impurities, are present in smaller quantities. The heavier hydrocarbons are often removed by a suitable method and, being liquids or easily liquified, are marketed as natural gasoline or bottled gases.

Natural gas is an ideal fuel. As such it finds application in a variety of heating and firing processes where its high energy content, cleanliness, and flexibility are appreciated and put to good use. In a few instances, particularly in the carbon black industry, it has been the raw material for the production of an important industrial product, although the non-fuel uses generally have been very limited. A very cheap natural gas is necessary for carbon black production, hence this industry is not located in Pennsylvania.

It is in looking to the future that natural gas appears to have unlimited uses, not only as a fuel, but as a raw material for the production of basic and special chemical materials. Within the past dozen years research chemists have found it possible to rearrange the fundamental structure of the hydrocarbons in natural gas in ways such as to produce numerous products of high value; for example, plastics, solvents, explosives, synthetic rubber, and aviation gasoline. Such processing makes it possible to manufacture products from natural gas—particularly from its heavier hydrocarbons—that have values far greater than the fuel value of the gas from which they are produced.

Natural gas is being consumed in the United States at a rate of over 2.6 trillion cubic feet annually. It has been estimated that the resources of this country amount to 85 trillion cubic feet with another 85 trillion potentially possible. This yearly consumption of natural gas is equal in fuel value to over 500,000,000 barrels of petroleum or about 100,000,000 tons of bituminous coal.

At the present time the greater part of the natural gas is used for the production of heat energy. It is logical to presume that the bulk of the marketed gas will be used for this purpose for years to come, especially since most States possessing large reserves of natural gas are deficient in reserves of coal. The natural gas industry is planning to boost the sale of natural gas for heating and domestic purposes during the post-war period. It has been suggested that the use of this gas for space heating, air conditioning, and refrigeration offers exceptional opportunities for marketing initiative and greatly increased consumption. Attention has been given recently to the use of natural gas for such special purposes as the maintenance of reducing atmospheres in metallurgical furnaces and for supplying accurately controlled heat for the manufacture of precision parts for guns, planes, tanks, and ships. Natural gas has been found to be a superior source of heat for the drying of fruits and vegetables. The impetus given to the dehydrated foods industry by the needs for conserving cargo space during the war is expected to result in the use by the general public of increased amounts of such foods after the war.

It is evident that natural gas will continue to supply the domestic and industrial consumer for at least several generations with a premium source of heat energy. From a technological point of view, the production of essential chemical materials and synthetic products appears to be a most promising method of utilization in the future, provided that the cost of raw material is not too high.

It may be interesting to outline several examples of these trends in the use of natural gas as a raw material for chemical synthesis. By modern methods of fractionation the constituents in the gas may be separated into relatively pure hydrocarbons and these hydrocarbons subjected individually to modern catalytic and thermal processes to give valuable products.

The butane in natural gas can be converted into butadiene which, together with styrene, forms the ingredients from which the Buna-S type of synthetic rubber is being produced. While only a part of the butadiene requirements of the synthetic rubber program will be filled by butane, it does represent a possible use for natural gas in the future.

The gas acetylene is an important hydrocarbon in chemical synthesis. Among other uses it is used as a base material for nylon, a replacement material for silk, and for the production of the synthetic rubber, neoprene. At present, most of the acetylene is obtained from calcium carbide, which is made from coal and lime in electric furnaces. Acetylene may be made readily by the high temperature treatment of natural gas or its constituents. Commercial installations are in operation at the present time and others are under way.

Natural gas can be processed thermally to give hydrocarbons which are basic materials for the synthesis of plastics. Since the plastics industry is generally considered to be headed for an expansion period following the war, considerable use may be made of natural gas. Other hydrocarbons obtained from the processing of natural gas are finding new and expanded uses as explosives, anaesthetics, fruit-ripening agents, aviation-type gasoline, and many others.

Natural gas is being produced, transported, and marketed by an industry that is looking toward the future. The reserves of this valuable natural resource are limited and a program of conservation to eliminate wastage and losses is in existence in Pennsylvania and other producing States. The trends in the future will be to place even greater restrictions on wastage, to obtain more efficient utilization, and ultimately to confine the use of natural gas to those operations where its inherent advantages can best be realized. Natural gas is a premium fuel and source of chemical products and its utilization should be accomplished with consideration of these qualifications.

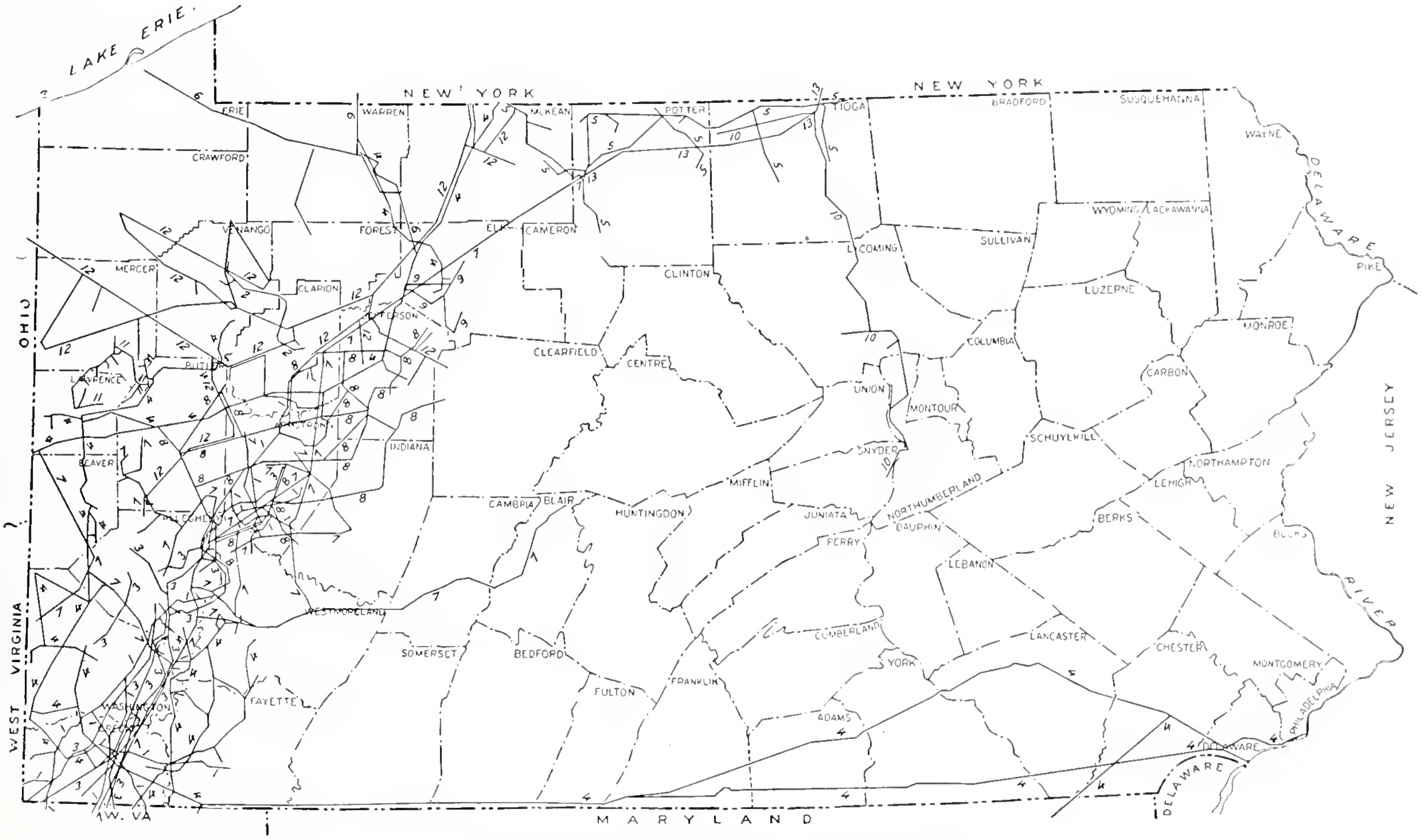


FIGURE 29. NATURAL GAS PIPE LINES

NONMETALLIC MINERALS AND THEIR INDUSTRIAL USE

NEXT to mineral fuels the greatest mineral wealth of the State lies in its diverse endowment of nonmetallic minerals. The nonmetallics include all those minerals that cannot be classed as fuels or metals. The group is therefore an extremely heterogeneous one and contains many unrelated materials. It includes such materials as limestone, dolomite, clay, ganister, sand and gravel, mineral pigments, slate, building stone, feldspar, talc, and others of lesser importance. With the exception of certain special cases, this group is characterized by a large volume of production and low price per ton, as is shown by the figures for past years. These minerals supply the fundamental material for many structural purposes as well as for portland cement, lime, glass, refractories, ceramic products, and some chemical compounds.

The reserves of these minerals in Pennsylvania are large although the familiar pattern of mineral development, the exhaustion of the best material first, is already evident. Some of the first applications of technology to correct this condition are described in the following pages. Continuation of this trend will make an almost inexhaustible reserve tonnage suitable for commercial work.

In addition to the common minerals, Pennsylvania has a great reserve in many materials not employed at present; this includes serpentine, sericite, some mica schists, many limestones, marbles, and other rocks of decorative value, and a group of clay minerals possessing a wide range of properties. These materials have one definite asset—that of place value. If any use can be found for them, their value in Pennsylvania will be far greater than if in areas remote from dense population and markets. Their presence in the Commonwealth presents a challenge to technical skill.

BENEFICIATION OF RAW MATERIALS FOR PORTLAND CEMENT

The cement industry in eastern Pennsylvania has pioneered in the application of mineral beneficiation to nonmetallic materials. Despite the fact that the technology of their beneficiation looked almost insuperable, careful research and bold development have produced a method of raw material control by mineral separation that is tending to become standard practice for all modern cement manufacture.

The technology of cement manufacture has progressed greatly in the past few decades. Present-day standards call for rigid control of the chemical constitution of the cement clinker as well as the control of the processing. Several kinds of cement have been developed, each with its own chemical composition and with its specific uses. In the past a single kind of rock or a simple mixture of rocks from the same deposit would supply the necessary chemical ingredients for cement manufacture. To obtain the correct compositions in other localities, however, it has been found necessary to purchase additional materials from outside sources.

Now, however, with the need for stricter control of the chemical composition of the product, and with the introduction of various types of cement, the manufacturer's difficulties are multiplied. Selective quarrying, blending, and the purchase of limestone add to the cost of production and are not entirely satisfactory methods of adjusting the composition. The alternative appears to have been found in the application of mineral separation techniques to the local deposits.

Raw material for cement manufacture is a delicately balanced mixture of four oxides, calcium oxide, silica, alumina, and iron oxide. The argillaceous limestones of eastern Pennsylvania contain various proportions of these oxides, but usually not in the proportions desired for modern cement manufacture. These cement rocks frequently have too little calcium carbonate (the source of calcium oxide), too much silica, and alumina, and may be contaminated with magnesia and alkali compounds which are detrimental to cement manufacture.

The mineral separation is accomplished in the following manner. The cement rock is first ground to such fineness that, to a large extent, the various minerals which constitute the rock are physically separated from each other. This finely ground rock is subjected to particle size separation by a centrifugal classifier. This separates the ground material into two fractions, one whose particle size is less than 15 microns (about .0006 inch) and the other whose particle size is greater than 15 microns. In some cases the size separation alone makes a sufficient correction in chemical composition so that the coarse product need not be further treated, but this is not always the case. Following size separation, the fine product, and sometimes the coarse product, are subjected to differential froth-flotation. This is a mineral separation method that depends essentially upon differences in reactivity of various minerals toward particular reagents. By careful selection of reagents and control of the conditions under which they are used a great variety of mineral separations can be made.

In cement-rock flotation several separations are made. The graphitic or carbonaceous material can be floated away from the remainder of the rock. This is usually done since the presence of carbonaceous material is detrimental to the subsequent flotation operations. After removing this material, the remaining rock is floated to produce a concentrate of calcium carbonate. The rock still remaining is then refloated to make a product rich in alumina, magnesia, and alkalies. This latter product is discarded, as is the carbonaceous material. The final remaining material is rich in silica and is used, along with the calcium carbonate concentrate, to blend with the straight run cement rock and produce a raw material of nearly any desired composition.

The great flexibility that mineral separation has made possible in the Pennsylvania cement industry will help greatly in forming a solid economic future for this industry. Technically, it has been shown that mineral separation, particularly flotation, is just as applicable to nonmetallic minerals as it has been to metallic minerals.

LIME

The production of lime in Pennsylvania is an old industry. Lime mortar was employed in the masonry of the earliest stone and brick buildings. Limestones of many types ranging from high-calcium to almost pure dolomite are widely distributed. Some of these are also employed in the manufacture of portland cement and these two industries are closely associated in a number of districts. Of the 309 lime plants reporting production in 1941, 89 were in Pennsylvania. This number is greater than in any other State. In addition, several small plants, intermittently operated, perform a useful purpose in supplying lime for local agriculture. Many farmers burn their own limestone with local coal or wood and so make a satisfactory lime for the soil.

In the early days of the lime industry most of the product was used for construction. It provided the only material for mortar and plastering walls. The recognition of its value for neutralizing acid soils and as a plant food led to its extensive use in agriculture. In the construction field, lime has lost ground steadily. The use of gypsum for wall plasters has excluded lime from a large market which it previously dominated. This shrinkage in the markets for lime would have been serious if it had not been compensated for by a rapid and steady expansion in the demands for chemical lime. The growth of the chemical industry has been accompanied by a large increase in the tonnage of lime consumed in many diverse activities. Lime is the cheapest alkali available and in addition has many properties related to its calcium content.

The development of nylon and other similar textile fibers and plastics, which utilize limestone as a necessary basic raw material in the early stages of the process of manufacture, suggests endless possibilities.

CLAY

Pennsylvania contains vast tonnages of clay and shale, suitable for a number of purposes. Clays, in general, are hydrated silicates of aluminum. They are used in the ceramic industries in the manufacture of structural clay products, porcelain, sanitary china, tableware, and in heat-resistant lining materials for the production of glass, and metals. Clays are used also as fillers in paper, linoleum, rubber, paints, and oilcloth, and in the purification of petroleum and other oils. Pennsylvania clays are not immediately suitable for all of these purposes, and large tonnages are transported here from considerable distances.

There is appreciable evidence to show that certain clays within the State may be treated in various ways to improve their properties so that they will become more valuable.

The white clays of Pennsylvania, residual kaolins found or produced in Centre, Blair, Huntingdon, Bedford, Cumberland, York, Lancaster, and Monroe Counties, are used chiefly as refractory or semi-refractory cements and linings for converters and ladles in steel mills, for whitening portland cement, and for certain filler purposes. The clays are usually pure white to light gray, and carry much very finely divided silica which cannot be removed by ordinary washing processes because the silica particles are so similar to the clay particles in size and specific gravity. With the improved washing, and particularly by the application of froth flotation, it should be possible to make these white clays acceptable for paper filling and for the manufacture of white tile, china ware, and other products requiring very pure clays. Present transportation costs alone on imported clays are probably three or four times the cost of beneficiation of local clays. There is little prospect of finding markets for the lower grades of Pennsylvania white clays unless mineral technology improves their quality.

Refractory clays are of great economic importance in this State. Preliminary experiments have already shown that as the economic pressure increases, clays not used now because of excessive impurities can be purified profitably. Even our highest grades of clay, however, are not always as pure as some found in distant States. The qualities of our most common clays should be investigated more closely, and attempts should be made to learn ways of making superior products in order to meet increasing competition and to reduce the costs of refractories to local industries.

Certain flint clays, and particularly the nodular "diaspore" clays of central Pennsylvania, contain more alumina than is found in most clays. Ways of removing much of the iron-bearing impurities are known, but they require finer grinding of the clay than is generally desired industrially. These clays remain, however, a definite source of aluminum. There is every indication that as supplies of domestic bauxite and the more easily imported aluminum ores become scarce, more and more attention will be paid to the utilization of the high alumina clays of Pennsylvania. It is particularly fortunate that large deposits of coal and limestone are found close to these clays.

GLASS SAND

West Virginia, Illinois, and Pennsylvania, in the order named, are the leading producers of glass sand. These three States account for about two-thirds of the national production. Since about 1923 the value of glass sand mined in Pennsylvania has ranged between three-quarters and one million dollars a year. During 1930-1932 there was a temporary drop in production, a reflection of the industrial depression.

The principal producing district of Pennsylvania is in the south-central part, from Lewistown to Mapleton in Mifflin and Huntingdon counties. Here the Oriskany sandstone is quarried where the rock has been weathered long enough to make it friable and easily crushed to its original quartz grains. The Pottsville sandstone in the northwestern part of Pennsylvania is also used for glass sand.

The sandstone is usually drilled and blasted, and excavated by power shovel. It is then crushed, washed, drained, and dried. All washed sand is screened after drying to remove oversize and foreign material. Most of the sand is sold as grains passing a 20-mesh sieve, and is shipped in box cars lined with kraft paper as large amounts of fine, dry sand would leak through any small crack or crevice.

Given a glass sand of satisfactory physical properties, the chemical composition is the most important consideration in establishing its value. In the manufacture of window glass and tableware, for example, the iron oxide content should be less than about 0.06 percent, while for high quality optical glass the maximum iron oxide content may be set as low as 0.005 percent.

Potters' flint, originally made by grinding flint pebbles imported from France, is now produced largely by pulverizing a high quality of glass sand. The resulting powder will usually all pass a 140 or 200-mesh screen, and most of the material is finer than a 325-mesh screen. Potters' flint is used in the manufacture of pottery products, chinaware, porcelain, sanitary ware, and porcelain enamel.

Much glass sand is pure enough to be used as a source of silica in the production of sodium silicate, and for other chemical purposes.

The tonnage figures of glass sand produced in this State do not clearly reflect Pennsylvania's leading role in glass manufacture, as much of the West Virginia production goes to glass plants in western Pennsylvania.

GLASS INDUSTRY

The glass production of the United States amounts to more than half of the world's production. The majority of glass plants are located in Pennsylvania.

These two facts alone should be sufficient to demonstrate the important role which the glass-producing industry plays in the economic life of our Commonwealth. In addition, however, we should remember that, despite the ancient origin of glass, the industry itself is still in its youth and must be regarded as one of the fastest-growing industries.

The origin of man-made glass goes back at least 4000 years but at that time it was used only for decorative purposes. With the beginning of the Christian Era, the blowpipe was invented and this simple instrument, which in its primitive form is still used today, represents one of man's greatest discoveries. With the invention of the blowpipe the position of glass changed completely. From a luxury which was traded at parity with gem stones, it changed into a necessity. But only in the last few decades, with the introduction of continuous melting operations and the invention of automatic machines, could glass take over the role which it plays today in our everyday life.

With the increased understanding of glass technology and with improved control of the composition and the melting of glass, the types of glass and the variety of uses have been rapidly increasing. Much of this recent progress must be credited to research and development done in the leading American glass industries.

We have many reasons to believe that the glass industry, which received a strong impetus during the war, will keep on growing after the war. There are three reasons for this assumption.

1. The limited availability of strategic materials such as metals made it possible for the glass industry to develop new uses and to conquer new markets for glass; many of them will, no doubt, be permanent.

2. Despite the leading role of the glass industry in certain fields, there was a great variety of glasses which were not manufactured in the United States to a large extent, but imported from European countries and Japan. The necessity of developing these glasses in this country not only makes us independent of foreign production but might even lead to new markets for these products in other countries, as in South America.

3. As compared with other industries, the glass industry has a unique position. It is based on raw materials which are available in practically unlimited quantities. Whereas experts predict the exhaustion of high-grade iron ores, copper, and other metals in the near future; the supply of sand, limestone, dolomite, and soda ash, the main raw materials for glass melting, does not face this fate.

Many of the developments of the glass industry are not available for civilian use at the moment and consequently it is difficult to visualize the development of the glass industry in the last few years. Research and development of a few pioneering enterprises have made available glass fibers in large quantities. This product, which is already replacing the textiles formerly used for electric insulation and natural cork for thermal insulation has a great future. The post-war building program will probably take full advantage of recent developments of glass fibers, as insulating material and of glass as a structural material. Foam glass or cellular glass, like glass fibers, is excellent insulating material which is absolutely vermin-proof. Plate glass will not only be used for windows in an ever-increasing rate, but its colored and opal varieties are destined to play a major role in the building of private dwellings, offices, and factories. Besides plate glass, the hollow glass tiles and bricks, which had just begun to be marketed in a large scale when the war broke out, will be more widely used. This trend is due not only to modern architecture but is based on economic reasons. It has been found that glass construction easily decreases fuel cost because of the utilization of the sun's radiation.

Our modern conception of lighting and the scientifically established fact that proper lighting increases the efficiency of workmen in the factories will have a strong influence on the glass industry. Not only large amounts of glass tubings will go into fluorescent lighting and indirect illumination but certain types of light sources for illuminating highways, for sterilizing lamps, and for the so-called black light to be used in connection with fluorescent materials, will call for special types of glasses. An entirely new development, the welding of glass tubings, makes it possible to install glass in many vital industries in the form of containers and for piping. Plants pasteurizing tomato juice, fruit juices and milk, are already taking advantage of glass which is gradually replacing stainless steel and copper. The fact that glass piping can be cleaned easily makes it preferable for these industries and breweries.

With the outbreak of hostilities, the glass industry, especially research and development departments, became very busy in finding substitutes for materials which had hitherto been imported from European countries or Japan. In some cases it was relatively easy, in others, however, special methods had to be developed to replace the skilled labor by automatic machines. Cover glasses for use with the microscope which are so much needed by scientists and physicians, were not made in this country at all but had been imported from Germany and Japan. The American Window Glass Company developed a new process and soon the shortage of this item was overcome. There was a general belief that Christmas ornaments made of glass could not be made available during the war. All these trimmings were hand-blown and produced by the domestic industry of Thuringia, Bohemia, and

Off-Hand Glass Blowing
by Edmund M. Ashe

Japan. Nevertheless, another Pennsylvania plant, the Corning Glass Plant in Wellsboro, got busy and developed a full automatic process which turned out millions of different Christmas trimmings.

In discussing the future of the glass industry, the question often arises whether or not the glass industry can meet the aggressive expansion of the chemical industry which produces a multitude of plastics and glass-clear resins. There can be no doubt that some of these materials will develop into serious competitors of glass, but looking on the development as a whole, we have to admit that plastics are more of a help than harm to the glass industry. First of all, the chemical industry has proved the immense value of systematic research. It has stimulated spending more time and money for fundamental research and that again reflects on the prosperity and the development of the glass industry. In addition, some of the organic resins have proved very valuable in combination with glass. The sandwiched safety glass is perhaps the best known example. Less known is the fact that a combination of glass fibers with organic plastics led to a new product with unexpected properties. Experimental samples of a plastic reinforced with glass fibers have produced tensile strength of over 80,000 pounds per square inch. This new material is now being used in aircraft construction because it possesses hitherto unattainable strength in proportion to its weight. This is a typical example where the combination of glass and plastic material opens up a new field to glass and it seems to be a very large field indeed.

REFRACTORIES

The manufacture of steel and of glass is an operation in which Pennsylvania plays a most important national role. In both of these operations the raw material, coke, iron ore, and limestone in the case of iron; and soda ash, limestone, and sand in the case of glass are mixed and completely fused together to form a molten mass. The furnaces or tanks in which these melting operations take place must be constructed of high-melting, heat-resisting materials called refractories. Included in the price of each ton of steel is the sum of one dollar which covers the cost of refractory material and installation.

Pennsylvania industry plays several roles in the field of refractories. These roles can be listed as follows:

1. Production and processing of native material.
2. Processing of foreign (out of State) raw materials.
3. Manufacture of refractory products from both domestic and imported materials.

Production of Native Raw Materials

Two major refractory raw materials are found within the State—ganister rock for silica brick and clay for the fire-clay refractories. Refractories from these raw materials constitute the bulk, about 90 percent of the furnace materials used in the steel, glass, and related heavy industries.

Ganister or quartzite analyzing 97-99 percent silica is the major constituent of silica brick. The rock occurs in suitable purity in several areas in more than adequate tonnages. It is quarried by the usual methods, transported to the mill, and without further processing is crushed and ground to make the silica brick. Present practice requires a high purity ganister since the economy does not permit any special purification of the raw material. Eventually as the better grades of rock are used up, or as the specifications for the brick are made more stringent, some beneficiation of the raw ganister may be required. The techniques of such a beneficiation have been worked out and need only be applied upon demand.

In contrast to silica brick, which has a fixed composition, the fire-clay raw material and brick composition varies considerably with industrial requirements. The essential chemical constituents of fire clay are silica and alumina. Other occasional constituents such as alkalies, lime, and iron are objectionable and must be present only in low percentages for the clay to be acceptable. The alumina content of fire clays ranges from 35 to 70 percent for useful material. The low alumina clays (flint) being less refractory are used in brick where temperature of use is not high. The high alumina clays (diaspore) are used for special duty fire brick and have a much higher price. The fire clay used for the average brick in steel plants and glass tanks has an alumina content of 35 to 50 percent.

The clays are quarried or mined by the usual method and then subjected to washing and sizing before use. Washing removes the coarser rock material and the heavier but fine, contaminating iron-rich materials.

Pennsylvania has been producing clay, especially in the central part of the State, for many years. The clay, principally the high-alumina clay, is occasionally associated with the coal deposits. While the potential clay tonnage is large, the clays at present usable without beneficiation are not extensive. Eventually, in order for Pennsylvania clays to compete with materials from other States, some scheme of beneficiation must be worked out to convert these potential deposits into usable material. Such beneficiation would probably involve a flotation process or some similar operation to separate the undesirable silica and iron-bearing material from the clay.

In recent years the clays having an alumina content in excess of 40 percent have taken on a new value as a possible source of the light metal aluminum.

Processing of Foreign Raw Materials

The refractory industry draws upon out-of-State sources for those raw materials not supplied in sufficient quantities at home. Such materials as magnesite for magnesia brick, chrome ore for chrome bricks, and such special materials as kyanite, zircon, forsterite, and beryl are imported as such and processed within the State. The operation of processing involves some purification of the ore by separation of the undesirable constituents, followed by calcination or other heat treatment that will prepare the material for the brickmaking operation.

Magnesite brick are made exclusively of imported material in the form of the natural magnesium carbonate. For use in refractories it must first be calcined, much in the manner of limestone, to the magnesium oxide, in which form it is ready to be manufactured into the final brick. Chrome ore must be similarly calcined before manufacture into brick. The processing of both native and foreign raw materials constitutes an important function of the local industries.

Manufacturing of Refractory Bricks

Pennsylvania ranks first in the manufacture of silica and fire-clay refractories and has held this position for some years. The close proximity of the mines and quarries to the industrial consumers and to the sources of fuels plays an important role in the position of the State as a refractory producer. In the clay industry the processors have been quick to apply the latest developments in the technology of fire-clay refractories. In the silica brick industry the progress has not been very marked, primarly because of economic limitations.

Most recent developments concern the basic brick industry. Basic brick differ from the clay or silica type in that they are composed of material such as magnesium oxide which is basic in character. The Pennsylvania refractory industries process material and manufacture basic brick although the source of the material is out of State.

Recent research has indicated the possibility of developing a basic brick from dolomite and serpentine. Both of these materials occur within the State in large tonnages of suitable purity. Development of these bricks within the next few years will show some remarkable gains.

SLATE

Pennsylvania slate is utilized at present as roofing material, using both the flat slate and granules; as millstock, including blackboards, school slates and structural slate; as floor and walk paving material; electrically as panels and switchboards; and as flour for filler in paint, linoleum, and asphalt.

The total sales of Pennsylvania slate for all uses in 1940 amounted to $2,609,801. When this amount is divided between numerous producers, each operating on a very thin profit margin, it becomes obvious that the slate industry is in a serious condition.

Adjacent to each quarry are waste piles representing 70 to 90 percent of the rock hoisted from the pit since the beginning of operations. These piles total hundreds of millions of tons and are continually growing. This quarry waste represents the difference between a successful and an unsuccessful industry. Not only are the piles themselves an outstanding economic factor, but they overlie important tonnages of usable slate, the recovery of which they make economically impossible.

Waste slate has been considered to be one of the most useless materials known, since its chief natural advantage, the slaty cleavage, is lost for commercial application. The chemical composition of slate is very similar to many rocks and hence offers no outstanding properties which might be utilized.

Preliminary investigations indicate, however, that the application of thermal and crystal chemistry to waste slate might yield new products of industrial significance. The melting range and constant carbon content of slate makes the mass production of lightweight aggregate for use in concretes economically feasible. The addition of calcium and magnesium oxides to slate allows the production of very credible mineral wool. Addition of various clays to fused slate forms ceramic materials whose properties indicate that they might compare favorably with those now on the market. Materials of this nature find uses as tile, ceramic ware, structural decoration, plumbing fixtures. Ground slate bonded with lime or another low-cost, quick-setting bond, would make an economical structural material to compete favorably with the lime-silica bricks now used. Foam glass to compete with cork can also be made from slate.

Artificially colored granules are now a $10,000,000 industry, taking most of the business from natural granules in spite of their appreciably higher cost. An inexpensive non-fading color applied to natural slate granules would undersell the artificial products and provide as good or better service. The same color applied to flat slate would allow the Pennsylvania product to compete with the colored slates from other States.

Large lime additions to ground slate give it the chemical composition necessary for the manufacture of portland cement. It would be possible to make a light (65-75 lb. per cu. ft.) concrete entirely from fused and treated slate.

Sales of flat slate may be materially increased by the application of aluminum foil to the under side. This cheap post-war material will increase the insulating properties of the slate and eliminate the characteristic "hot roof."

Many other products can be made from slate, but economic considerations make the production of most of them impractical.

The strategic geographic location of the Pennsylvania slate areas, coupled with the availability of the raw slate at little cost, will enable products made from this slate to be economically practical. These factors, as well as previous neglect of technological applications, have been ignored in the formation of the present conception that waste slate is practically useless. It seems possible that a new industry might be initiated, based entirely on the heretofore "valueless" waste slate.

STONE

In 1941 Pennsylvania produced stone valued at over 25 million dollars, which represented over 23 million tons of material. Stone is therefore a low-priced commodity at the point of origin. However, stone represents a wide field of interest as it is used in structural, building, ornamental, fluxing, and chemical activities. There should be an excellent opportunity for expansion of the stone industry in Pennsylvania for the following reasons:

(1) The State is ideally located with regard to markets due to the density of population in nearby areas. (2) A great variety of stone is available within the State, including granite, gniess, and schist in southeastern part; sandstones in the western and central parts; and limestone widely distributed. (3) Little attention has been given to developing markets or more efficient quarrying methods. Although much general information is available, the deposits have not been studied to determine points of superiority and the most suitable uses to which the different types may be put.

A marked revival in house building and general construction may be expected in the immediate postwar years. Many building stones of Pennsylvania with their attractive colors, durability, and low up-keep cost have much to recommend them for such work.

METALLIC ORES

AS INDICATED by the tonnage figures the mining of metallic ores in Pennsylvania has made an impressive record in the production of iron, copper, gold, silver, lead, zinc, chromium, and nickel. This is an exceptional diversity of mineralization and the possibility of new discoveries in the future is by no means out of the question. Present production is restricted almost entirely to the mining of magnetite iron ores, with some by-product copper, gold, and silver. With an increasing world-wide depletion of mineral resources the desirability of making a thorough scientific inventory of the metallic ore reserves of Pennsylvania is apparent. The geologic environment is such that the application of modern geological and geophysical techniques might bring much to light of interest. The most promising possibilities appear to lie in the development of zinc and iron ores. The magnitude of the zinc mining industry in eastern Pennsylvania during the last century indicates that other ore-bodies may be found there.

Magnetite, hematite, limonite, and siderite iron ores have been mined in Pennsylvania. Only magnetite has been found in deposits of sufficient size to permit continuous operation. Hematite ores of the "Clinton" type, well known in New York and Alabama, occur in thin beds. To date such deposits have not been amenable to large-scale mining. It is possible that with modern methods of treatment a large body of low-grade material could be mined and concentrated to commercial grade. The chief interest in siderite ores has been the production of a material which could be calcined to produce a typical iron-red pigment for paint.

At the present time the greatest interest and the greatest opportunity for accomplishment lie in the treatment of the brown ores, sometimes called brown hematite. The ore is actually a limonite and, correctly speaking, probably should be called goethite. Ores of this type were produced in the past to the extent of over one million tons per year. Cessation of mining operations was due principally to the introduction of the Lake Superior ores at low cost. These ores with their high iron content and cheap mining and transportation costs have dominated the iron ore markets of western Pennsylvania. However, there is evidence now that the high-grade ores are approaching exhaustion. This tendency has been accelerated by the record breaking demands for steel caused by the war. Either lower grade material will be shipped or concentrated before shipment, a more likely procedure. In either event the competitive position of Pennsylvania iron ores will improve. The possibility of restoring some of the old "brown hematite" ore bodies to activity is of interest.

These ore bodies tend to be comparatively small and localized, and, in the light of present knowledge, cannot be expected to exceed a few million tons at a maximum. However, certain factors favor the operation of such deposits. They are minable by open pit and they can be worked with machinery at a fraction of the cost of hand mining. Modern methods of concentration make it possible to take low-grade and non-uniform material and produce a high-grade, uniform concentrate, suitable for blast-furnace feed. The ores are hard and their physical condition makes them excellent for blast-furnace use. It has been estimated that when crushed and properly sized their physical properties are such as to effect a substantial saving in coke consumption.

Clay and dolomite have been considered typical nonmetallic minerals. Their commercial use has been related to their physical properties more closely than to their chemical composition. Recent developments have altered their industrial position and they may now be considered to be metallic ores.

CLAY AS AN ALUMINUM ORE

The common clays are essentially hydrous aluminum silicates. They have not been used extensively as aluminum ores because of the difficulty of breaking down the silicates and because cheaper material has been available in the bauxite ores which the United States produces in Arkansas and imports from foreign sources. While this material has been growing scarcer the demand for aluminum has increased. The clays and some related minerals inevitably will become commercial ores.

Pennsylvania has a very large tonnage of high-alumina clays. How many million tons may be depended upon is not known. These clays occur in quantity in Clearfield County and elsewhere in close association with the flint clays which supply the refractory industries. Alumina content is variable; in exceptional cases it is reported to be high where diaspore, an oxide of alumina, is present. It is believed that this material will eventually become important as an ore of aluminum.

DOLOMITE

Dolomite, a variety of limestone with a high-magnesia content, is widely distributed. High-grade material with a low impurity percentage is not common. This rock can be used as an ore of magnesium. Magnesium, a light weight metal, has been extraordinarily useful in the airplane industry and has many other uses. It is possible that sufficiently pure dolomites may be found in Pennsylvania to attract this industry to the Commonwealth.

IRON AND STEEL IN PENNSYLVANIA

Six factors are essential to the establishment of a successful iron industry, (a) plentiful supplies of suitable ore, (b) abundant fuel, (c) limestone for flux, (d) power for blast, (e) experienced operators, (f) adequate market for the iron produced.

All of these were present in Colonial Pennsylvania in greater degree than in any of the other colonies and even before the Revolution, Pennsylvania was established as the center of American iron production. In the rapid westward surge of settlement which followed the Revolution numerous deposits of iron ore were discovered in all parts of Pennsylvania and the building of forges and cold-blast charcoal-iron furnaces followed rapidly clear across to the western boundary of the State. The dense forests that covered large areas of the new lands afforded ample wood for charcoal fuel and as these were depleted in the eastern portion, their place was taken by anthracite. Further west, vast deposits of bituminous coking coal

Steel Works in Winter
by Roy Hilton

were developed in their turn to replace charcoal, and the rise of Pittsburgh to industrial power provided a new focus for the iron industry. A new and constantly growing market for its products was brought about in supplying the needs of the growing west. The progress of iron production may best be gauged by a consideration of data covering pig iron manufacture.

Statistics of early iron production are not plentiful and the proportion of that production provided by Pennsylvania before 1810 can only be guessed. In that year, however, the proportion was nearly 50 percent. It was reduced to about 25 percent in 1820 and rose to almost 35 percent in 1830, with about the same proportion in 1840. In 1850 it was 50.6 percent and rose to 70.6 percent in 1860. Ten years later it was 50.3 percent and from 1870 to 1916 it remained almost constantly over 40 percent. During all of this time the volume of both national and Pennsylvania production steadily increased but the relative standing of Pennsylvania declined somewhat because of the building of large steel plants in Ohio, Indiana, Illinois, and Alabama. This decline has been more marked since 1916 with Pennsylvania's share of national production ranging from a 39.7 percent in 1917 to a low of 24.2 percent in the deep depression of 1932, but averaging about one-third of the United States total. Twice in the depression period—in 1933 and 1935—its pig iron output was exceeded by that of Ohio. Since 1935 however there has been a large margin in favor of Pennsylvania.

The Cast
by Edmund M. Ashe

Up until the depression decade 1930-1940 no foreign country or State had made more pig iron per year than Pennsylvania. Both Germany and Russia have forged ahead under their respective "four year" and "five year" plans in preparation for self-sufficiency and for war, and their annual tonnage now exceeds that of Pennsylvania. No longer can the proud boast be made that iron and steel production in Pennsylvania exceeds that of any other State or nation. It is probable that post-war Germany will show greatly reduced production. The yield from Russia, however, may further increase.

From the above outline it may be seen that while Pennsylvania retains supremacy in iron production in the United States and is challenged only by Germany and Russia among the foreign producers, its proportional production has been seriously diminished.

The second World War has placed upon the entire iron and steel industry an enormous burden which has kept all plants operating at or near capacity for the past two years.

The question of future trends in iron and steel production and especially production in Pennsylvania is at present unanswerable. So many unknown factors are involved that the best informed authorities can venture only guesses as to probable trends. Some of the factors affecting the situation may be briefly considered.

A very considerable increase in production capacity has been made by the various steel companies and by government-financed, company-operated, emergency war plants. The Defense Plant Corporation has spent about one billion dollars in steel plants, with especially large installations at Homestead, Pa., Chicago, and Geneva, Utah, besides 120 smaller plants and additions throughout the country. The question of what is to become of this war-expanded plant equipment when peace is restored is sorely troubling executives in the steel industry. In spite of the fact that decrease in demand for steel seems inevitable, many influences will be brought to bear upon government agencies to preserve these plants, especially in areas where no such plants existed before the war.

Supplies of Raw Materials

The enormous demand for steel has strained to the limit the iron ore resources of the Nation. Shipments of ore from the Lakes region in 1943 aggregated around 90 million tons and early exhaustion of all higher grade ores in that region was freely predicted. There are vast reserves of lower grade ores, however, and more and more these will require costly beneficiation. This will greatly increase their cost delivered to plants in Pennsylvania and will tend to restore to Pennsylvania iron ores the advantages which they possessed before the discovery of the Lake Superior ores. The Pennsylvania ores are widely distributed, being found in workable quantities in more than half of the 67 counties of the State. These are usually of lower iron content than the good Lake Superior ores and will generally require concentration or other beneficiation to make them acceptable to modern furnace operators. They will enjoy, however, a distinct advantage in their nearness to the centers of iron smelting—a matter of 150 miles maximum—as compared to the 800 to 1000 miles' haul from the upper Lake Superior ports to Pennsylvania furnaces. No comprehensive and adequate survey or study of local iron resources has ever been made, although extensive descriptions of developed deposits were published by the second Pennsylvania Geological Survey. Earlier mining and concentrating methods were poor and wasteful and extraction was superficial. It is high time that a systematic resurvey be undertaken, together with detailed studies of beneficiation and handling methods. It is believed by many that such a survey will reveal extensive reserves of workable ore.

Competition from Light Metals

The war has brought about an imposing expansion in production of aluminum and magnesium, especially for airplane production. It is freely predicted that post-war uses of these metals will offer severe, and possibly ruinous competition to steel.

Leaving aside for the moment the inferior structural properties of these metals in comparison with steel, we need only remember that present maximum capacity for aluminum is about 1½ million tons. If all of this should be used to displace steel it could replace only about 2½ to 3 million tons out of a steel productive capacity of nearly 100 million tons. If all the aluminum that could be produced in existing American plants should be rolled into sheets, the total would be less than 8 percent of the 1941 demand for steel sheets.

Such competition, while annoying, should not be at all destructive to the markets for iron and steel. Furthermore, the tendency seems to be in the opposite direction, with high-strength alloy steels replacing in important parts, aluminum alloys of lower strength possibilities.

C. F. Kettering of General Motors says we will have steel airplanes long before we have aluminum automobiles.

Production of magnesium has increased 90 times since 1939. It costs now 20½ cents per pound and annual production is 265,000 tons. This also would make small headway against 100 million tons of steel. There are, moreover, other handicaps for magnesium. It is used chiefly in castings and can be flat rolled but not forged. It resists corrosion poorly and offers some fire hazard because of its ready combustibility.

A highly optimistic view of the post-war outlook for steel was expressed recently by Lawrence S. Hamaker, Assistant General Manager of Sales, Republic Steel Corporation, Cleveland, in an address given before the Robert Morris Associates in Buffalo (Reported in Steel, Nov. 1, 1943, vol. 113, p. 59)—

"As to the general post-war outlook for steel Mr. Hamaker said Republic officials are optimistic, though with some reservations.

"A detailed survey seems to indicate that we will have remarkably little disturbance of the major markets we enjoyed before the war.

"We expect all kinds of consumer's durable goods to move in very large volume and this means huge tonnages of steel. The automotive industry will enter the peace with the largest backlog of unfilled demand in its history and will be several years catching up with it.

"We anticipate the largest residential building boom the country has ever seen. There is about a ton of steel in even a small home.

"The railroads will be almost literally worn out and their deferred maintenance alone will account for steel in large volume.

"The American farmer will come out of this war in the best financial condition in his history. Mortgage debt is being retired before it is due. He will buy implements, machinery, buildings, fence, and many other products made of steel.

"The post-war highway program has made headlines in recent weeks. Highways are reinforced and guarded with steel.

"A rosy picture of the outlook can be painted and truthfully so, yet it is not all roses. I think there is little possibility that our 100 million tons of capacity can be fully employed for a good many years after the war, no matter how good business is. This year we will produce about 93 million tons. In the boom year of 1929, we produced 63 million tons.

"Most post-war additions to steelmaking capacity have been extensions to existing plants, because balancing out these establishments with relatively few new facilities was the quickest method of increasing production with the least expenditure of money and material. There has, therefore, been no major change in the geographical distribution of the nation's steel capacity. If, as is very likely, steel production drops to something approaching pre-war levels, many problems will arise in determining which plants are to produce steel. An even decrease in operating rates throughout the industry cannot be expected. For one thing, obsolescent plants which have been revived to meet wartime needs probably will be abandoned. In addition, it is possible that some of the new capacity, which in post war will represent extreme over-capacity, sush as plates for shipbuilding, will not operate at all. Some of the new plants built in the Far West, vital to the war program, will be seriously handicapped by high costs.

"Fortunately, the steel industry has no problem of reconversion to peace-time production and can swing immediately into its normal lines. As a matter of fact, it is now estimated that only 20 percent of our industries will have serious reconversion problems and there probably has been too much alarm on this subject."

C. D. King, Chairman of the Operating Committee of the U. S. Steel Corporation of Delaware, reviews the many remarkable advances in technical practice in production of iron and steel in the period from 1918 to 1943.* In this quarter century metallurgy developed from an art to a science and the applications of science produced really marvelous results in magnitude of operations, capacities and efficiency of equipment, quality of products, and safety and welfare of personnel. These advances are the result of intensive and extensive study of all phases of the industry and of devoted research in the fundamentals of metallurgy and their application.

There is nothing in this history of the practical results of industrial research to indicate that the next 25 years may not see an equally great improvement.

Outlook for Pennsylvania

The foregoing brief review of conditions in the American Iron and Steel Industry seems to indicate a probable healthy post-war condition in the industry as a whole.

Our study of statistics of Pennsylvania production in comparison with national production through 133 years shows Pennsylvania always in a dominating position and still going strong. The State has the highest concentration of producing and fabricating companies and plants, and these have fully profited by the technical advances of the past quarter century and have participated in the devoted work that has brought them about. They have had their full share in the plant improvement and expansion of the war years and apparently are in as good condition as the companies and plants of other producing States. It is reasonable to expect that these plants will continue to hold their position in the forefront of American production and that Pennsylvania will have every opportunity to retain its traditional leading place in the production of iron and steel.

Necessity for Continued Education and Expanded Research

The technical advances of the past have resulted from continual study and research on the part of technically trained experts working in close cooperation with experienced operators. Everything points to the necessity of continuing and constantly improving the training of men who are to carry on this research and to make up the experienced operating personnel. Metallurgical schools have a big job cut out for them in giving this improved training.

Everything also points to the advantage of further research and anything that can foster and stimulate this research will redound to the advantage of the iron and steel industry and to the State in which it is conducted.

POWDER METALLURGY

Powder Metallurgy is the name that has been applied to the making of metal aggregates from the metals in powder form. While this has become of great importance only in the past ten years, the techniques employed are not at all new. In fact some of the oldest fabrication of gold and certain other metals was carried out in ancient times by cementing together fine grains of the metal by pressure and moderate heating.

The first notable use of powder metallurgy was the production of ductile tungsten for incandescent electric lamps. Tungsten, reduced from tungstic oxide in fine powder form, could not be melted to a lump form because of its exceedingly high melting point. When, however, the powder was compressed into a dense briquet and the briquet was heated nearly to its melting point by passage of a heavy electric current, the grains of tungsten powder were caused to sinter or slightly fuse together at their surfaces. When the resulting sintered block was reheated and hot worked, recrystallization of the metal took place and formed it into a homogeneous crystalline mass. This could be hot worked or cold worked and drawn into fine wire or rolled into sheets.

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* Technical Advances in the Period Between the Two World Wars (Mining and Metallurgy, January, 1944, pp. 14-17).

An identical process has been used to make very pure iron without even melting the metal, and the product is free from contamination which usually accompanies the melting of metal in a crucible.

The technique of powder metallurgy therefore involves first, the production of the metals in suitable powder form; second, the forming of the metal or mixture of metals into a "compact" of desired form; third, the sintering or surface melting of the powder grains to form the metallic aggregate.

By use of mixtures of metals, alloys can be produced that cannot be made by ordinary melting methods. Non-metallic substances can be bound together with metal powders by sintering.

A highly important use of this is the cementing of tungsten carbide or tantalum carbide, extremely hard materials, into super-efficient cutting tools by use of cobalt or other metal powders as binders. This has made it possible to machine hard, tough metals which could never be cut before, and to cut softer metals at undreamed of speeds.

The pressure moulding of the "compact" makes it possible to form the metal or alloy aggregate into the exact shape of tool or other article desired and to make it to very exact dimensions.

Much has been done to develop and improve the details of powder metallurgy methods, but much more can and should be done. Every detail of the processes needs to be studied in order to determine the best combination of operations to produce the best results.

Several companies in Pennsylvania have pioneered in the applications of powder metallurgy.

There is a great future in this field of metallurgy and immense possibilities for application of its techniques in the manufacture of a variety of products. It is an especially fertile field for research and such research is bound to produce worthwhile results.

THE POST-WAR FUTURE OF THE FOUNDRY INDUSTRY

In general, the post-war status of the foundry industry in the State, as well as in the Nation, will depend to a large extent upon the foundry operators themselves. Competition from other methods of fabrication will be extremely keen and for certain branches of the industry to survive will require painstaking attention to detail. From present indications the steel foundries will probably be in the best position and the cast iron foundries in the most precarious situation. A little consideration will be given in turn to each branch of the industry.

Cast Iron

Although the cast iron foundries in some sections of the country have not done too well, even with the tremendous upsurge in the metal industries as a result of the war, the outlook is not entirely without hope. Cast iron does possess some inherent advantages that qualify it admirably for certain applications. Vast improvements have been made in the field of cast iron metallurgy in the past ten or fifteen years and every producer of cast iron should acquaint himself with these improvements to use them to the best advantage. It is realized that the nature of cast iron production is unique in that a majority of the companies producing this material are distinct entities operating one or two foundries. As a consequence many companies feel that they are not in position to employ technically trained personnel. This conception is a mistake for those companies that will survive are those who understand fully the flexibility of product at their command and are fully prepared to take advantage of this flexibility. This will be possible only through employment of trained personnel or thorough use of other means at their disposal. By the latter is meant active membership in such organizations as the American Foundrymen's Association, and the use of the laboratories of the alloy producers, the research institutes, and the colleges and universities.

Developments in the industry will probably result from the following: (1) Close control of the melting operation, especially as regards the cupola. This will

Casting in a Foundry
by C. Frank Schwep

include control of all materials going into the furnace, including the air, which will be controlled to maintain a constant weight of oxygen and in some cases a constant quantity of moisture. (2) The iron as it comes from the furnace probably will be inoculated or ladle treated to develop the best possible structure. (3) Alloy additions will continue to be used on a large scale. The use of ladle treatments and alloy additions is designed to control the structure of the graphite and the nature of the matrix, both of which influence the mechanical properties. (4) Sand control will become increasingly important, so that the mold is properly conditioned to receive the metal. Further improvements in the properties of the casting will be possible by carefully planned and executed heat treatments. The need for proper metallurgical supervision is apparent when these possibilities are considered.

Malleable Iron

In recent years the malleable iron industry has suffered a decline. However, with the development of quick annealing cycles and the so-called pearlite malleable iron there is a good possibility for a resurgence. Low carbon, highly alloyed irons of the Ford crankshaft type, which belong to the malleable class in a sense, offer some interesting possibilities in the development of new fields for castings.

Cast Steel

The outlook for cast steel is particularly bright. Through intensive research and development work the producers of cast steel have focused attention on their product. Centrifugal casting of gear blanks and cylinder barrels promises further possibilities for this method of fabrication. Exhaustive work is being done and will be continued in the future on the melting and casting stages. Heat treatment, which once signified merely a simple annealing operation, will involve henceforth a whole range of operations extending to water quenching and tempering of castings.

Melting Brass
by Catharine Morris Wright

Nonferrous Castings

It is somewhat difficult to predict exactly what the post-war conditions will be in the nonferrous castings industry. The probability is that many new developments are being born under the present emergency and the full importance of these will not become apparent until after the war. Undoubtedly improvements are being made in melting and casting technique with the urgent need for conservation. At the same time, and for the same reason, new alloys have been developed wherein strategic metals are being replaced by less strategic ones. Development in the light alloy castings field, especially magnesium castings, has been and will continue to be rapid. Many types of casting alloys have been developed which are susceptible to improvement by heat treatment. Further alloys of this type will be developed in the future and heat treatment of nonferrous alloys seems destined to become more and more important.

NONFERROUS METALS

Although the term "nonferrous" literally means all metals other than iron, the principal metals which are usually included under this category are copper, aluminum, magnesium, zinc, tin, and lead. Some others which are important but which are generally used only as minor alloying elements are antimony, beryllium, bismuth, cadmium, and manganese. This list could be extended but it tends to circle back and include elements that are more commonly used as companions of iron in steels. Of the so-called precious metals, only silver has attained a considerable industrial use (e. g., in brazing alloys, in aircraft-engine bearings, and in electrical conductors) and these are usually not included with the nonferrous metals.

Of the six named principal industrial nonferrous metals, copper has long been far in the lead in tonnage produced. But with the progress of the Second World War, the outstanding role played by military aircraft in both aerial and surface operations of all modern combat forces resulted in an abrupt and astonishing increase in the production and utilization of the light metals, aluminum and magnesium, for aeroplane construction. The most remarkable increase has been in the output of magnesium. In consequence, the tonnages of aluminum and magnesium are now respectable fractions of that of copper, while on a volume basis the comparison is still more favorable to the light metals. Thus the total U. S. output of refined copper in 1941 was 1,495,000 short tons; of primary aluminum, 307,500 short tons; and of magnesium, 15,000 short tons. But the expected production in 1943, based on figures through July, had grown to 445,000 short tons of aluminum and 200,000 short tons of magnesium. (Figures for copper for the same period are not available.) It appears highly probable that aluminum ultimately will become the largest-tonnage nonferrous metal.

The interruption of the supply of tin ores from the Far East, a result of enemy action in the present war, leaves the tin industry in such an abnormal state that forecasts for the post-war period can be made with little assurance. Up to the present, the country has done no tin smelting except under stress of war. The Longhorn smelter on the Gulf coast—a location which permits a short over-water haul of South American tin ores—is definitely a wartime necessity. Time will reveal whether this smelter can pay its way in a peace-time economy or must yield to European competition. Under the pressure of a tin scarcity we have learned to make many tin-consuming products—good bearing metals, for example—with little or no tin. Where the substitute has proved to be as good as or better than the old alloy, a restoration of the availability of tin may not mean a return to the use of tin, in which case the Nation's consumption of tin might not again equal that of the prewar period. In any event, there appears to be no likelihood that Pennsylvania will have any part in the smelting of tin.

Primary refined lead produced in the United States in 1941 was nearly 600,000 short tons, but in this industry Pennsylvania has shown no recorded activity in recent years. In the smelting and refining of zinc, however, Pennsylvania is leader of the Nation, although all the zinc ores it uses must come from outside the State.

Zinc. Of the 675,275 short tons of zinc reduced in the country in 1940, Pennsylvania smelted 26 percent. The 1941 production was 881,500 short tons, with Pennsylvania still smelting about one-fourth. This smelting of zinc is the State's largest part, and virtually her only part, in the primary production of the nonferrous metals. The presence of zinc smelting and refining in Pennsylvania, which produces no zinc ore, may be attributed to (1) the State's plentiful supply of fuel, (2) its location in a populous area with markets at hand, and (3) proximity of the steel industry, whose galvanized sheet metal products are the greatest outlet for zinc. During the war (1941) the distillation capacity of the Pennsylvania zinc industry has been increased by an amount equal to 27 percent of the previous retort capacity of the Nation. Because of the vital assets mentioned above and the presence of ample plant capacity, it is expected that in the post-war period Pennsylvania will retain her dominant lead in the reduction of zinc from its ores. Whether, in the future, zinc will hold its place as an eminently useful metal may depend in some measure on finding new uses for it. It may be that stainless steel or other corrosion-resistant alloys will partially displace galvanized iron. Aluminum and magnesium also may compete with zinc to some extent, although an increased use of alloys of the three together is to be expected.

No remarks on Pennsylvania's zinc industry would be complete without mention of the sulphuric acid which is made as a valuable by-product from the sulphur eliminated in the roasting of zinc ores. The tonnage of acid produced in this way in Pennsylvania has increased almost regularly since 1932 and in 1941 it amounted to 351,722 short tons, with a value of $2,986,120.

It may be added here that a substantial part of the zinc smelted in Pennsylvania goes into the State's large and well established industry for the production and fabrication of brass and bronze. In 1941 this industry employed 10,000 persons and made products valued at $93,000,000. The products and practices of the industry are of such long standing that, while steady improvement and modification are to be expected, radical developments in the near future are unlikely. On the other hand, it might be as convincingly maintained that an industry with established habits is a good field for the planting of new ideas.

Light Metals. When the pressure of military urgency subsides, the vast production capacity for aluminum and magnesium which this country and Canada will have is virtually certain to be far greater than that which can be supported by the peace-time needs of North America. It is true that the insistent pressure of availability may force the light metals into structural fields in which they have not heretofore been used, and that the results may be beneficial to both the economy and the culture of the nation. Yet it is highly probable that, to keep the light-metal industry as a whole from starving, a considerable part of its production capacity will have to be decommissioned or demolished. Unless this is done by an act of government (which might or might not be carried out with regard to economic laws), it is to be expected that those producing plants which survive will be those which have the most economic processes and the best situations with respect to raw materials, power, and markets. Even so, the production and use of aluminum and magnesium in the post-war period will certainly be considerably greater than ever they were in the pre-war era.

The decisive requirement of cheap electric power for the reduction of aluminum from its oxide may be expected mainly to exclude Pennsylvania from the primary production of this metal for some years to come, although an important share of its fabrication should continue to be done within the State. However, when the bauxite ores now used are sufficiently depleted, the high-alumina clays of Pennsylvania may become a major ore of aluminum. Methods of extracting aluminum from such clays are already known, but at present the use of bauxite is more economical and the techniques involved are well established. If or when Pennsylvania becomes a major producer of aluminum ore, she has also a chance of becoming an important primary producer of the metal itself. With the change from the bauxite type to the clay type of ore, radical changes in the technology of reduction of aluminum will be necessary. It it not required that the new methods be merely modifications of present practice. Entirely different procedures are conceivable. If, when the time comes, Pennsylvania is ready with an economic, working technology for the reduction of aluminum from the State's clays—a technology deliberately conceived and developed to fit the State's natural facilities—then she can produce the aluminum herself. Furthermore, the development of such a technology would advance the day when the Pennsylvania clays shall become aluminum ore. If the State is not ready, other areas will supply the technology, and the capital and labor, and will take the reward.

FUTURE OUTLOOK FOR BRASS, BRONZE, AND BEARING METALS

The terms brass and bronze are frequently confused. For example, in the wrought brass industry a high-copper brass is usually referred to as a bronze and among the casting alloys one of the lowest copper-containing alloys is referred to as bronze; namely, manganese bronze. It is, therefore, best for the present purpose to discuss the subject under two broad classifications; viz, copper-base alloys, cast and wrought.

In Pennsylvania the output of wrought copper-base alloys in relation to the total national production is insignificant. Only three concerns of importance are producing wrought products. One of these is devoted to production of bronze in the true sense of the term: viz, copper-tin alloys; another produces machinable brasses: viz, copper-zinc alloys; and the third, previously a producer of wrought copper, is now producing cartridge brass. Many foundries are producing copper-base alloy castings, including bearings.

In the post war years abundant supplies of aluminum and magnesium coupled with the development of easily machinable alloys of these metals and alloys of high physical properties, may become increasingly competitive with copper-base alloys. Recent researches seem to indicate that aluminum alloys may be substituted for copper-base alloys in the manufacture ot plumbers' goods. Zinc-base die castings are also being substituted to some extent for such alloys. The same is true of plastics. Some are predicting that the price of aluminum in the post-war era will be far below the present ceiling price. With approximately three to one ratio of specific gravity, aluminum alloys would seem to have the most promise as a substitute material.

It is generally believed that the industry will not face the catastrophic conditions in the post-war era that it did after the first World War or after the collapse of the boom of the twenties. This prediction is based upon the fact that price levels have been under control and have consequently been held down. Supplies of raw materials: viz, copper, tin, lead, nickel, and secondary metals, have been under rigid control and no doubt will continue to be held under such control until the cessation of hostilities and perhaps after. Under such control the accumulation of inventories on the part of producers and consumers will not be possible. The only large accumulation will be in the hands of the Government. It is hoped that some orderly method may be evolved whereby this accumulation will not be, as it was after the last war, dumped on the market at the time there was almost complete absence of demand. This matter is now having the very earnest consideration of the Government. Plans are under consideration—among them accumulation by the Government as insurance against a future emergency or to be released gradually in a market in which they may be absorbed advantageously.

THE ROLE PRESENT AND FUTURE OF SECONDARY METALS IN PENNSYLVANIA

Secondary metals, sometimes called scrap or junk, are a very important source of material. Indeed, this supply has been referred to as the world's greatest mine. The value of the metals recovered has exceeded one and one-half billion dollars in a single year. As a result of the war much greater emphasis has been given to metal conservation, partly because of the need of what has been termed "quick metal" and partly because of the much greater necessity for conservation of strategic metals such as nickel, tin, chromium, and manganese.

There has been a tendency to associate the term "secondary" with the physical characteristics of metals and alloys, and some consumers have tended to distrust secondary metals. Indeed, certain manufacturers have emphasized the fact that they use only virgin metals and thus infer superiority of product. With suitable metallurgical control, secondary metal is first rate metal prepared for a second or repeated use. By refining from scrap, it may be purer than the virgin metal, dependent on the extra refining operations through which it passes. Some authorities classify secondary metals into two general groups:

(a) Waste resulting from the necessary processing (fabrication) of metals and alloys into articles of commerce.

(b) Waste obtained from structures, mechanisms, utensils, after they are worn out or become obsolete.

With respect to some of the important metals, particularly under post-war conditions, the second class is more important than the first. However, in war time, the second group cannot play so important a role.

Of the iron and steel produced in the United States prior to the war, more than 50 percent came from scrap. Of the principal non-ferrous metals rather more than one-third came from scrap metal. From the tonnage standpoint, the iron and steel industry was about twenty times larger than the non-ferrous industry, although with regard to the value of the product the ratio dropped to about two to one.

During the war period much of the recoverable scrap, defined as waste, obtained from structures and mechanisms, is not produced unless new machines, equipment, and structures are provided to replace those which become obsolete. The automotive, building, and railroad industries provide excellent examples of instances from which very large quantities of secondary metals may become available at the end of the war, as replacements are made. The fact that no further use will be found for many of the machines of war as soon as hostilities cease will provide scrap or secondary metals in such immediate quantities as the world has hitherto not witnessed. Economical use of these metals will provide a universal opportunity for conservation of our domestic ores.

Up to the present time the secondary metal problems, as related to the ferrous industry and to those industries dealing with non-ferrous metals, appear to be quite different.

In both the steel and cast iron industry an important factor is concerned with suitable segregation of scrap so that it is known what alloy content is present. Adjustment of scrap additions can then be made to provide the desired alloy content in the furnace melt. In the earlier days of the steel industry, trouble was frequently encountered when nickel and chromium scrap steel became associated with charges used in furnace operations which were to provide straight carbon steels. This naturally led to a modification in the desired heat treatable characteristics of the steel. A further problem related to the introduction of metallic tin from charges of tin-bearing scrap to the charge for the open hearth.

During the war period much effort has been directed toward steps to minimize the amount of scrap produced and for economic reasons, if for no other, efforts in this direction will be prosecuted in the post-war period. Such considerations have related to tool design and reduction in the amount of chips as well as the number of inspection rejects, reduction of butt-ends, and use of coils rather than cut-lengths, care in positioning of blanking dies, and correlation of varying sizes to insure minimum waste. However, much scrap will necessarily result in processing and the problem then becomes one of suitable organization for handling. The complexity of this organization is naturally dependent on the type of plant under consideration and the consequent variety of metallic alloys utilized in either manufacturing or fabrication processes. In any case, the problem is usually one of segregation and collection under supervision of trained personnel who can enlist the full cooperation of all department supervisors and foremen.

Various types of equipment have been developed for this purpose and one company has presented details of a rather elaborate layout for a chip reclamation plant on a conveyor principle. Many of these problems are perhaps more engineering than metallurgical in character.

In an aeronautical corporation an important contribution has come from the simplification of specifications. Thus while 90 percent of the aluminum alloys used to be made of six different alloys they now are made in two standards. Incidentally, this company recovered and put back into the war program more than 11,000 tons of all kinds of metals.

One of the large electrical companies is recovering waste metals at a rate of one million pounds a day, whereby an average of 14 carloads of metal are shipped to mills, foundries, and smelters every day. Approximately 90 percent, by weight, of the total is steel and iron and 10 percent non-ferrous. On a value basis the steel and iron represent only 40 percent and the copper, aluminum, tin, and lead are worth 60 percent of the returns.

It would seem that collection and segregation will continue to be the basis of the ferrous secondary metal industry so far as one is concerned with alloying elements. Recovery of the usually small amounts of special alloy present in steel does not appear to exhibit any favorable economic features, especially since the alloyed scrap can be readily utilized in such form by direct addition to furnace or cupola charges. Thus the basis of a large tonnage of the new N. E. (National Emergency) type steels has been dependent on the fact that with suitable scrap collection it was found that moderately large amounts of alloy steel containing about one-half percent nickel and one-half percent chromium resulted from regular steel practice without the addition of any virgin nickel or chromium. This base "scrap alloy" has been utilized widely, with certain other limited alloy additions, as the basic of steels having good hardenability needed for various war services.

In the non-ferrous field, secondary recovery has been stated to be a direct function of the effectiveness of classification and segregation of scrap. Commercial practice, dependent on economies of metal production, has usually left to waste much metal that could not profitably be treated even though it contained percentages of a particular element greater than that in the richest primary ores. Such waste is usually dependent on wide geographical distribution. No doubt suitable nation-wide cooperation could be directed toward considerable minimization of this secondary metal wastage.

Current technical practices in the recovery of metal from scrap may be considered in terms of aluminum, copper and copper-bearing scrap, zinc, lead, tin and antimony, and other alloys. Little can be gained by attempting to describe in any detail the present well-known methods for dealing with their recovery but a few comments indicative of the magnitude of the industries in 1941 may be of interest.

During 1941 the number of foundries and manufacturers using purchased scrap aluminum rose to about 1000. After the War Production Board granted permission in 1942 to those only who proved themselves able to make the most efficient use of scrap by avoiding contamination or undue melting losses, only fifty plants are reported to have produced secondary aluminum ingots. In 1941, the gross weight of scrap totaled nearly 130,000 tons and the alloy recovery approximated 85 percent. The return of large quantities of battle scrap and the certain flow of other obsolete aluminum materials, following the end of the war, might well exceed the post-war demand for aluminum castings. As the high grade domestic supply of bauxite decreases, this huge secondary supply might well serve as an important source of aluminum metal.

The million tons of copper scrap, in 1941, including such alloy constituents as zinc, lead, tin, and nickel, represented almost three-quarters of a million tons of metallic copper. The total metal recovery has been given as 90 percent of the gross weight of the scrap. Many problems will arise as a result of profligate use of this metal under war time conditions. Efforts will be directed towards methods for recovery of copper, which have hitherto been uneconomical, from end products carrying 5 to 10 percent of the metal. Thus it has not so far been attractive to develop and install plants to recover copper from copper-clad steel, since the total scrap volume has been limited until war requirements profoundly increased the quantities produced.

In normal times about half the secondary zinc originates in brass scrap, and this is recovered in secondary brass ingots. The greatest source of unalloyed zinc consists of galvanizers, dross and skimmings, and marked reduction in steel galvanizing resulted in a much reduced flow of these by-products. The automobile wrecking campaigns were stated to have brought out thousands of tons of zinc die castings and metallic zinc scrap. Automobiles may be one of the most important sources of zinc in the immediate post-war years, possibly augmented by return of some of the zinc-base alloys from the battle fields. In 1941 the gross weight of zinc scrap and residues consumed totaled slightly over 200,000 tons, from which about 155,000 tons of zinc were recovered.

Secondary lead is largely of the demolition type, the large tonnage accruing from spent accumulators and cable sheathing. In 1941 scrap totaling nearly half a million tons showed about 78 percent recovery. The tin-bearing alloys and lead-bearing drosses were relatively unimportant. However, some of the lead finds a dissipative outlet in the metal consumed annually in pigments. It has also been stated that the secondary lead industry is the most widely dispersed of any in the non-ferrous field. During 1942 at least 275 plants handled enough scrap to be classified as remelters, smelters, or refiners.

Secondary-tin sources are listed in three principal categories, (a) drosses and residues from tin-plating, (b) demolition scrap from bearings, solders, etc., and (c) tin plate scrap. However, recovery of secondary tin as refined metal is confined mostly to detinning plants, and such recovery of tin is a highly developed technology, dependent on digestion in hot caustic soda in the presence of an oxidant, followed by reduction by direct electrolysis or precipitation as oxide by treatment with carbon dioxide.

The necessity for restrictions of the use of tin has profoundly modified the secondary metal industry and the use of the electro-tinplating method, using half as much tin and little or no process waste, appears to be established. New metal jointure alloys, in lieu of tin solders, may not be discarded after the necessity of war disappears, unless tin can be sold at a very attractive price.

Nearly all antimony is recovered in its lead-alloy form. Arsenic, bismuth, and cadmium do not appear to have any existing secondary technology.

The value of the so-called precious metals has been such that economic considerations have always insured a reasonably satisfactory secondary-recovery technology.

THE PENNSYLVANIA STATE COLLEGE

School of Mineral Industries and Experiment Station

State College, Pennsylvania

PUBLICATIONS OF THE MINERAL INDUSTRIES EXPERIMENT STATION

The Mineral Industries Experiment Station represents the organized expression of the research spirit in the school. Research in the mineral industries had its inception in the earliest days of the College. Under the direction of Dr. Evan Pugh, the first President of the College, three members of the first graduating class in 1861, completed theses on mineral industries problems.

The first organized investigations were begun in 1893 and four bulletins covering scientific studies were published between 1896 and 1900. The Mineral Industries Experiment Station was organized in 1919 but existed in name only until 1929 when a special legislative appropriation provided funds for research on petroleum. Since 1929 a continuous and expanding program has permitted the investigation of many problems in pure and applied research. Several of these problems have been of a highly practical industrial nature and have been carried to completion by a cooperative arrangement between industry and the College. This arrangement, which has combined the equipment and personnel of the school and the financial support of interested parties, has resulted in the successful solution of problems which neither industry nor the school could have accomplished alone.

The following list includes all publications of the Mineral Industries Experiment Station. With the exception of such as are out of print, copies may be obtained from the Director, Mineral Industries Experiment Station, The Pennsylvania State College, State College, Pennsylvania, at the price stated. All checks and money orders should be made payable to the Treasurer of The Pennsylvania State College.

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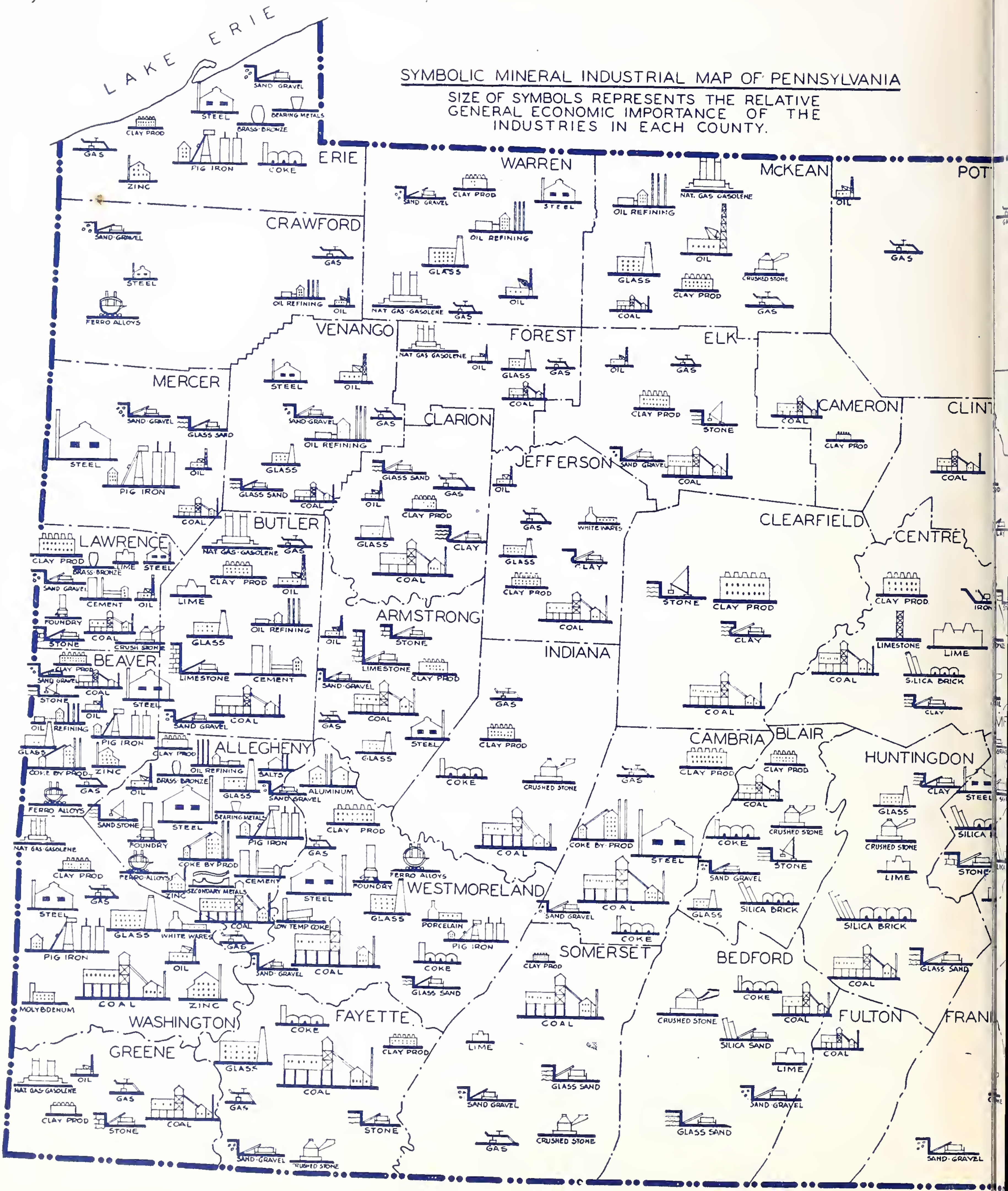
SIZE OF SYMBOLS REPRESENTS THE RELATIVE
GENERAL ECONOMIC IMPORTANCE OF THE
INDUSTRIES IN EACH COUNTY.



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